The
ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XVII No. 7 JULY, 1956

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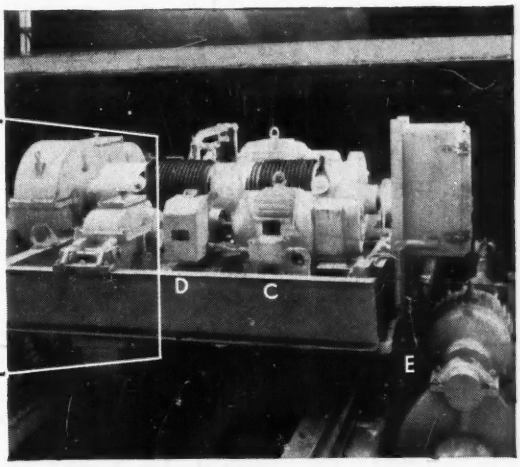
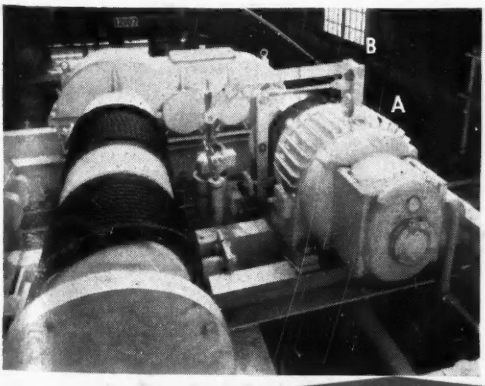


Metrovick equipment is well on top in this 10-ton Wharton overhead shop crane. The hoist is an 18-h.p. 720 r.p.m. M-V motor fitted with a thrustor-operated brake giving precise control with stable creeping speed on load. The need for inching is thus eliminated. Drives for the long travel and cross-traverse are M-V 10-h.p. 715 r.p.m. and 3-h.p. 700 r.p.m. type MZ slipring motors respectively. A 6-inch Perigrip brake operates on the cross traverse. Write for details of the range of M-V a.c. and d.c. motors, control gear and Perigrip electromagnetic brakes for crane drives.



In the illustration (left) A is the 18-h.p. 720 r.p.m. hoist motor fitted with Stacreep thrustor control B. The long-travel drive, motor E, is shown at the top of page. The 3 h.p. cross traverse motor is seen at C and the 6-inch Perigrip brake at D.

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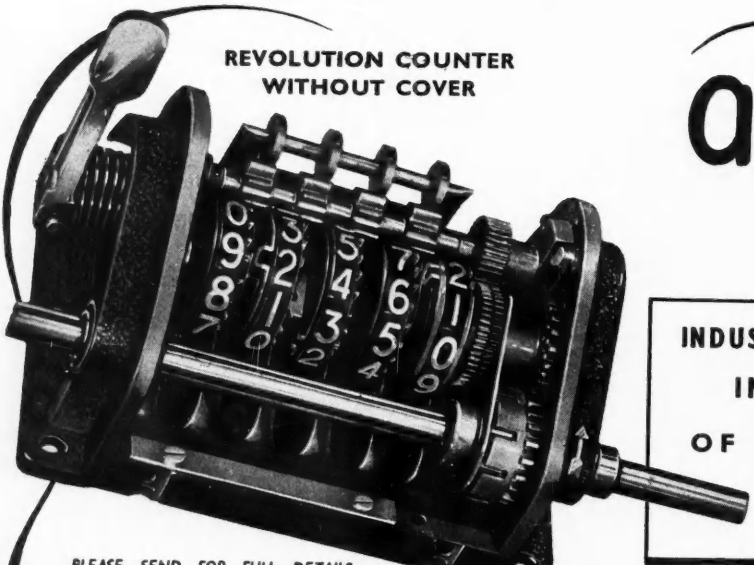

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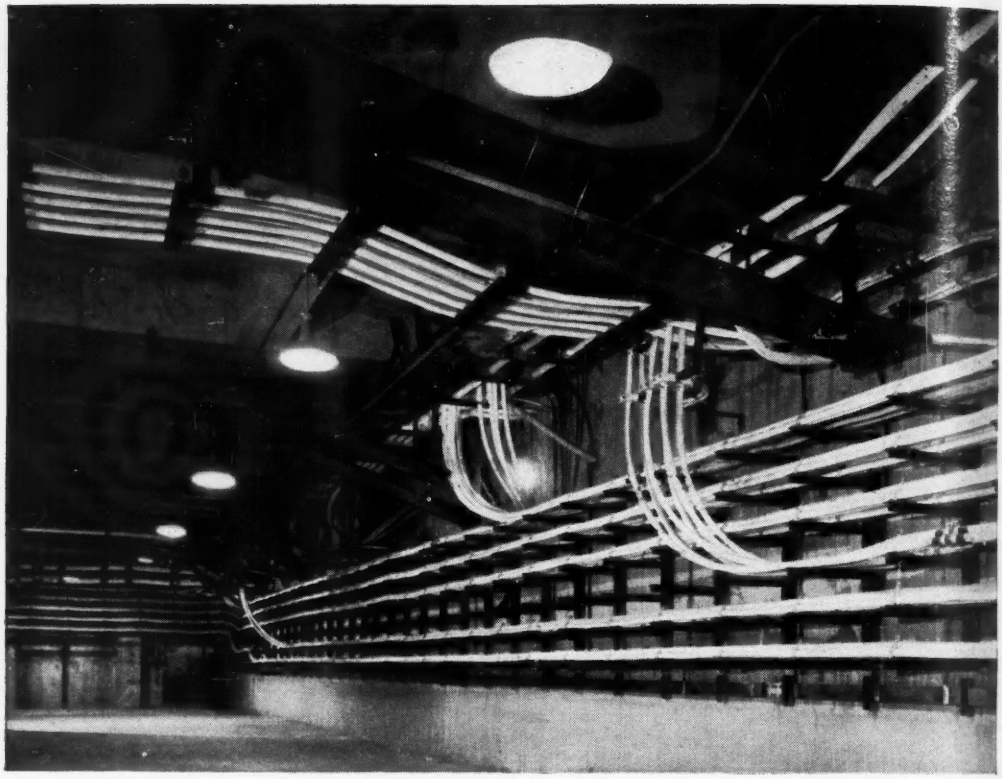

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *HIGH-SPEED ROTOR BALANCING MACHINE*

A balance, capable of testing rotors at speeds of 1000 to 200,000 rpm, has been constructed. This speed range is achieved by the use of two transducers, a broad-band demodulator, and a photoelectric phase-sensing system, which are independent of frequency over a wide range. The unit operates with vertical or horizontal spin-axis mountings. The pick-up and computer units are arranged separately, so as to ensure ease of mounting and flexibility of control. The balancer can be operated remotely with a servo-motor controlled by the unbalance signal, the motor driving the phase dial which determines the amount and location of the unbalance. The rotor mounting assembly is made of magnesium, in order to obtain low inertia and therefore high sensitivity. The rotor mounting ring is supported by three rubber mounts, these being selected because of their damping characteristics and low resonant frequency. The transducers measuring static and dynamic rotor displacement are mounted in a phenolic block, and the displacement signals are amplified and discriminated against a square-wave reference voltage. The square wave is used for accurately timing the signal entering the demodulator. The unbalanced mass is computed from the indicator reading, and the angular position is read from a phase dial. Measurements are made at two arbitrary planes through the rotor, and an inverter is used to obtain a phase relation between the two displacement signals, which are obtained at one of the two planes. The demodulator serves to filter all spurious frequencies in the operating range, except odd harmonics of the rotor frequency. A vacuum phototube is used for wide-band frequency reponse. A cathode follower serves as an impedance transformer.

● *PLATING BY THERMAL DECOMPOSITION*

The deposition of thin films of protective metal, such as nickel, cobalt, tungsten, and molybdenum, on metallic surfaces can be carried out by placing the part to be coated in a chamber filled with a decomposable metal-bearing gas mixed with a carrier gas, and then heating the part to the decomposition temperature of the gas. A recently patented improvement of this process consists of effecting ionization of the plating gases and establishing an electrostatic field, the workpiece to be plated acting as an electrode. In this arrangement, the action of the electrostatic field is to cause ionized gases to be directed towards the workpiece at high velocity, thus enhancing the efficacy of the plating process. It is claimed that the process can be further improved by exposing the gases to radioactive substances prior to their admission to the plating chamber. By making the workpiece of negative polarity it receives positively charged molecules, causing decomposition of the metal-bearing gases into metallic ions and negatively charged ions of the gases of decomposition. The metallic ions lose their charge to the cathode, i.e., the workpiece, so that a firm metal deposit is produced, while negatively charged decomposition products are repelled with great force and at high velocity from the plated surface. If the positive electrode is $\frac{1}{8}$ in. from the workpiece surface, an electrostatic potential of 1000 V will suffice. Materials which can be plated in this way include steel, copper, aluminium, cast iron, brass, and magnesium. The temperature to which the workpiece must be heated depends upon the plating gas used and, where gaseous metal carbonyls of tungsten, nickel, chromium, and iron are used, temperatures should range from 325 to 425°F.

● *DETERMINATION OF THE DYNAMIC MODULUS OF PLASTICS*

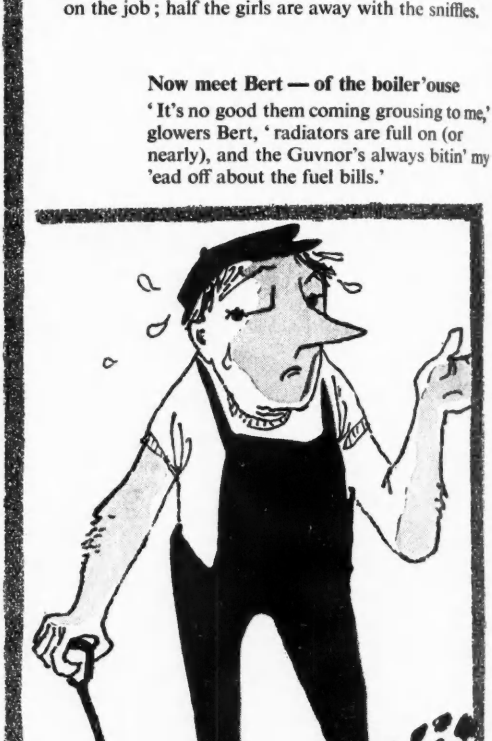
A special device for determining the dynamic modulus of plastics has been developed. This apparatus is based upon the vibrating-reed principle and is claimed to avoid the shortcomings of other devices of this type. While the idea of a vibrating cantilever is mechanically simple, the apparatus usually employed suffers from the drawback that a considerable time is taken up in determining the amplitude-frequency curve for a particular reed length and that errors are introduced due to the graphical method used to determine the resonant frequency and band width, and also to the use of a telemicroscope to measure amplitudes. In the apparatus developed, a rod, on which the clamp holding one end of the specimen is mounted, is supported near its end by two springs, while its other end is attached to the driver. These springs, which are made of copper-beryllium strips, are bolted at each end to a solid support, the rod extending through the centre of the strips perpendicular to the width, and therefore ensuring its uniaxial motion.

Meet Perishin' Fred!

Very fond of a grouse is Fred. Doesn't have to look far either. 'Like the perishin' North Pole in this perishin' factory', growls Fred. But at least he stays on the job; half the girls are away with the sniffles.

Now meet Bert — of the boiler'ouse

'It's no good them coming grousing to me,' glowers Bert, 'radiators are full on (or nearly), and the Guvnor's always bitin' my 'ead off about the fuel bills.'



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● *INSTRUMENT FOR MEASURING AND ANALYSING SOUND*

A new electronic instrument, developed for the measurement and analysis of sound in industry, serves as a meter for measuring overall sound levels and operates as an analyser by measuring sound in each of eight octave bands to determine noise peaks. In addition, it can check sounds in narrower frequency bands. The importance of these features will be appreciated if it is realized that overall noise measurements alone provide little indication of the specific frequencies which may be causing a given noise problem. A single industrial machine can produce sounds of many different frequencies with widely varying intensities. Each frequency band must therefore be studied individually, to locate the potentially harmful noise source and to enable corrective action to be taken. When used as a sound-level meter, the instrument picks up noise through a microphone. The sound-pressure level is measured by passing the electrical signal through attenuators and amplifiers to a meter; the reading appears in decibels, the measuring range being from 24 to 150 db. In the analyser section of the instrument, noise is filtered into any of the eight principal octave bands, from 75 to 19,200 cps. Noise peaks in each of these bands can then be measured individually. For finer analysis, by frequencies within the octave bands, continuously variable filters are used. It is claimed that the instrument makes it possible to produce noise-contour maps of industrial areas, since sound-level readings and analyses of frequencies and intensities at different distances from noise sources can be used to plot a detailed map.

● *RADIO PULSE SYSTEMS POWERED BY RADIOACTIVE MATERIAL*

A recent invention envisages the utilization of radioactive substances for the generation of radio pulses, and it is claimed that pulse generators of this type are particularly suitable for unattended operation over long periods. The continuously generated power available from radioactive elements is, of course, very small, and voltages are only of the order of several millivolts per curie. However, by utilizing a pulse generator in which the radioactive energy is slowly stored and rapidly dissipated at intervals, very high peak powers (of the order of kilowatts) can be obtained from reasonably small amounts of radioactive material. With a suitable radioactive substance, such a pulse generator has a useful life of many years, during which it requires no servicing or replenishment. By way of example, cobalt-60 has a half-life of 5·3 years, and strontium-90 has a half-life of 25 years. In the pulse generator the charged-particle high-voltage cold emission of the radioactive material is stored as electrical energy in a suitable high-voltage capacitor. In a typical proposed generator of this type, a 50-kW peak power pulse can be obtained every 16·7 sec by using 100 curies of a beta-emitter, or every 167 sec by using 10 curies. It is claimed that the peak power voltage can reach 10,000 V without difficulty. This voltage is much lower than the usual beta-particle voltage, and it is expected that, by improving the new technique, higher voltages than 10,000 V can be stored, so that peak powers of 150 to 1000 kW can be produced. To effect intermittent switching of the capacitor to a magnetron without requiring an auxiliary switch or timer, use is made of a magnetron containing a gas at low pressure and ensuring breakdown of the resistance of the gas when the capacitor voltage attains its predetermined maximum value.

● *ALTERNATIVE TO SINTERING PROCESS*

It is well known that sintering constitutes practically the only industrial method used up to the present for manufacturing articles composed of mixtures of metals with solid particles which are insoluble in the metal mixture. This method consists of mixing powdered metals with other powdered metals or materials and subjecting the mixture to compression, generally at elevated temperatures below the melting point of the metals used. Hitherto, the preparation of such mixtures by starting from molten metal was not practical. This is due to the fact that, even when the solid particles to be incorporated have specific gravities very near that of the molten metal, stable mixtures cannot be obtained, usually because of the high interfacial tension between the molten metal and the solid particles. A typical example showing the action of surface tension is that of alumina grains, which float on the surface of molten aluminium, in spite of the fact that their density is much greater than that of the metal. In a recent patent the inventor proposes the use of special wetting agents which are capable of lowering the interfacial tension between the molten metal and the solid particles to be incorporated in the mixture. These agents are chosen from the group constituted by

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the elements sodium, potassium, caesium, lithium, magnesium, calcium, strontium, and barium, and by compounds (other than halides) containing these elements. It is claimed that by this method solid particles of emery, sand, corundum, granite, silicon carbide, boron carbide, tungsten carbide, and even diamonds can be dispersed and incorporated in molten metals to form abrasive bodies.

● *ELECTROLYTIC ANALYSIS OF ZINC ALLOYS*

An electrolytic procedure has been developed for the precise determination of very small amounts of impurities in zinc and zinc-base alloys. Zinc is one of the more important metals commercially, and in both the galvanizing and the zinc-base diecasting industries knowledge of the constituents of the metal is highly important. The physical properties of the metal are a function of alloying and trace metals such as copper, lead, tin, and cadmium. Generally, the presence and quantities of such metals in zinc alloys are conveniently and accurately determined by polarographic analysis, this method being based on the interpretation of current-voltage curves obtained during electrolysis of an alloy solution. However, copper and zinc, when present in relatively large quantities, interfere and cause inaccuracies in the results. In the new method the sample is dissolved in an electrolyte and placed in an electrolytic cell. A mercury-pool cathode in the base of the cell is connected through a stopcock to a mercury reservoir, and the anode is a platinum-gauze cylinder at the top of the cell. The solution to be analysed is electrolysed at a potential which permits zinc to remain in the electrolyte but which withdraws copper, tin, lead, and cadmium into the mercury pool. When electrolysis is complete, the residual zinc solution is discarded and replaced by fresh electrolyte. Electrolysis is then resumed at a lower potential, chosen to redissolve the trace elements, singly or collectively from the mercury. It is claimed that the new method increases the sensitivity and precision of polarographic determinations and eliminates the difficulties of previous methods.

● *GLASS FOR ELECTRONICS*

A recent paper gives a comprehensive survey of latest developments in the use of glass in the electronic field. By a novel patented process a fine-quality, clear, high-purity silica glass can now be produced which has such a low coefficient of thermal expansion that it is indestructible by thermal shock. In fact, it can be immersed while red-hot into ice-water without damage. At the same time, its melting point is so high that it can be continuously used at 1800°F, and intermittent use at 2500°F is possible. Because of its high degree of homogeneity and low attenuation constant, this glass is suitable for ultrasonic delay lines. Other possible uses include transistors and similar types of crystal components. By applying a metallic oxide to the glass surface at elevated temperatures, borosilicate and aluminosilicate glasses can be provided with an electrically conductive coating of controlled resistivity. By treating glass tubing and glass rods in this way, precision resistors can be made. Relatively soft glasses—also called "solder glasses"—have been developed, and these are especially suitable for sealing to metal at temperatures lower than those required with conventional glass-to-metal sealing techniques. These glasses are used principally to prevent the heat distortion of sealed components or to provide a hermetic joint which can be broken easily. Parts to be assembled by this method are supplied with solder glass, preglazed at the edges to be joined. Another important development is the production of ferromagnetic materials of good permeability by binding carbonyl-type irons in a glassy matrix. Cores of this type are reported to have a low loss factor.

● *PHOTOELASTIC MATERIAL EXHIBITING GRAVITY STRESS PATTERNS*

The photoelastic method of testing a design for peak stresses and finding the most suitable shape from model tests is gaining increasing acceptance, the range of usefulness improving as new plastic materials with photoelastic effects are developed. The latest addition is a material with a very low modulus of elasticity in the region of 600 psi and with a good fringe-constant of 0·8 psi per fringe in 1-in. thick material, available in sheet form for two-dimensional work. A beam made of this material will show clearly the stress pattern due to its own weight only; rock and earth pressures can thus be investigated conveniently by the same simple technique applied to externally loaded models, and the more complicated techniques, using gelatine between glass walls, heated material viewed through an oven, or centrifugal effects, are no longer needed for general purposes. The low modulus of elasticity also imposes only low shearing stresses in a bond of this material with stiffer materials, so that the choice of glues for two-component investigations is facilitated. From the same group of polymers opaque materials can be made with a wide range of moduli of elasticity from 600 to 15,000 psi, according to manufacture, and these materials, although not photoelastic themselves, can be used in compositions simulating the effect of differences in moduli of elasticity in metals or in metals and plastics combinations. An attractive possibility is, for instance, the investigation of local stresses in prestressed concrete by pretensioning, gravity loading, and external forces.

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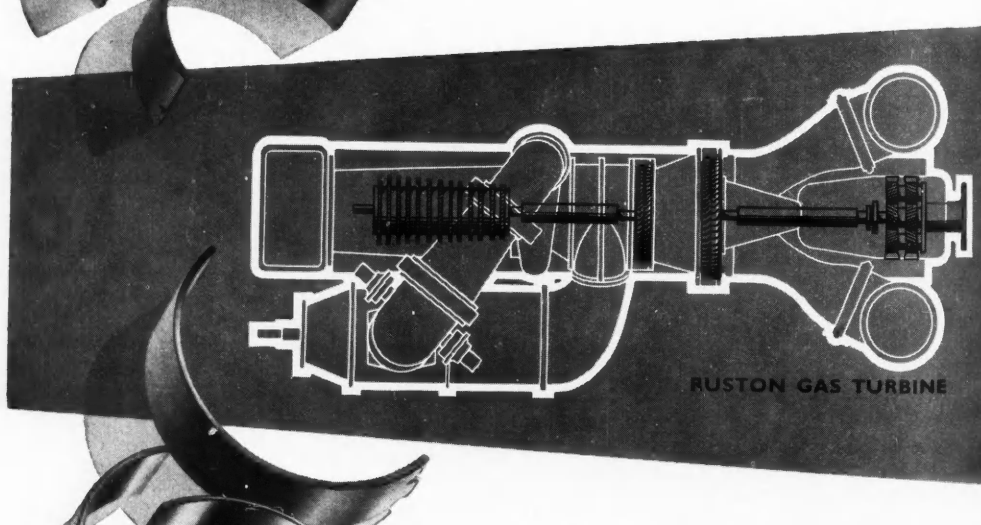

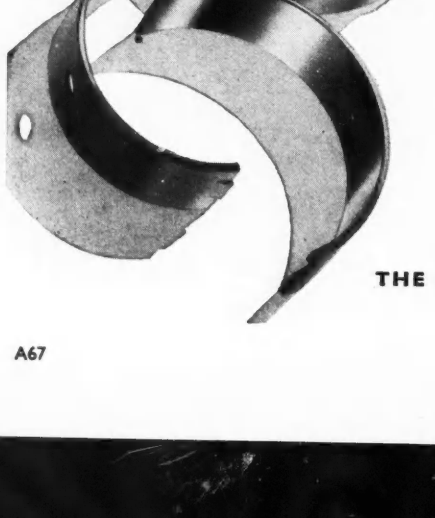

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● *CHROMIUM-PLATING PROCESS FOR ALUMINIUM AND TITANIUM*

A recently developed chromium-plating process makes it possible to produce deposits from 0·002 to 0·030 in. in thickness on aluminium and titanium surfaces. While a suitable surface pretreatment is required, the new process does not involve the successive deposition of zinc, copper, and nickel on aluminium before the chromium can be applied. The pretreatment consists of first passivating the metal and then reactivating the surface during deposition of a bonding coat of aluminium. In the case of titanium the pretreatment consists of immersing the part in a special surface-activating bath after surface cleaning. The chromium deposit is claimed to be 15% denser than conventional hard chromium coatings and to be so ductile that hammering causes flow of the deposit but no cracking. The deposit adheres so tightly to the base metal that the plated part can be twisted or bent without separating the coating. It is reported that, after heating a chromium-plated tube to 1300°F, the uncoated internal aluminium surface melted, while the tube retained its form and the chromium coating was not discoloured. This would appear to indicate that alloying between the base material and the coating had been effected or, as has been suggested, an atomic bond had been produced. Chromium-plated aluminium is being used in the production of moulds for reinforced plastics, because the chromium plating has an improved surface and no parting agent is required to obtain mould release. It is expected that the chromium surface will increase the life of aluminium moulds sufficiently to make them competitive with steel moulds.

● *THE ROLE OF MERCURY IN THE CORROSION OF ALUMINIUM*

The corrosion of aluminium equipment in a number of cases has been attributed to mercury contamination. Investigators point out that in most cases it is thought that the contamination originated from broken thermometers or other mercury-bearing apparatus. It is, however, often difficult to prove that mercury contamination is the actual cause of corrosion, because in many cases where mercury is definitely indicated, only small amounts of mercury can be found on an aluminium surface by standard analytical techniques. Radioactive tracers provide a convenient analytical tool for measuring the partition of small amounts of radioactive material between different portions of a system. For this reason, and because the distribution of radioisotopes on a surface may be determined by autoradiographic techniques, the use of such tracers was resorted to in a recent study of the corrosion problem. For this purpose radioactive mercury was obtained by neutron irradiation of mercuric oxide in a nuclear reactor, yielding two radioisotopes of mercury, namely, mercury-197 and mercury-203. The experimental work was devoted to answering several general questions, i.e., (1) the kinetics of mercury pick-up, (2) the dependence of pick-up of mercury upon the mercury concentration and the alloy, (3) the relationship between mercury pick-up and corrosion, and (4) details of the process by which the attack of mercury upon aluminium takes place. It was found that mercury concentrations below one part per million caused no acceleration of the corrosion of aluminium, but it was also noted that the higher the purity of the aluminium, the greater was its tendency to corrode in mercury-contaminated solutions. Another important finding was that aluminium specimens contaminated with mercury and then heated in air were less susceptible to corrosion by 3·5% sodium chloride solution.

● *EFFECTS OF HIGH-FREQUENCY VIBRATIONS IN GRINDING*

The author of a research paper of recent date points out that there exists evidence that vibration problems still exist in grinding, even in the absence of the strong resonant vibrations causing chatter. In order to investigate these problems systematically, an ultrasonically vibrated grinder was built, in which workpieces could be vibrated at amplitudes up to approximately 0·001 in. at frequencies in the range from 10 to 18 kilocycles per second. In general, the test procedure involves mounting the workpiece on the transducer and grinding as in ordinary surface grinding. Conventional grinding tests without induced vibration were carried out in the same manner, except that the transducer was not vibrated. The results of the investigation definitely demonstrate that small vibrations at high frequencies can improve surface finish, can reduce the incidence of thermal cracks, and can minimize the effects of variations in hardness within a grinding wheel. There was some doubt as to the significance of the improved surface finish and apparently lower metal temperature, since only a very narrow range of grinding conditions was represented in this first series of tests. Consequently, numerous additional tests were made over a wide range of conditions, including depth of cut, cross-feed, table speed and work material. This investigation indicates the possibility of applying high-frequency and even ultrasonic vibrations to selected operations to improve the grinding process. It would also appear to explain some of the well-known characteristics of grinding associated by precision-grinder operators with the use of sound or noise as an indication of the process.

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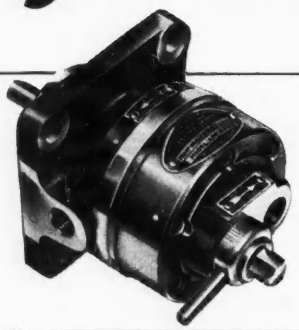

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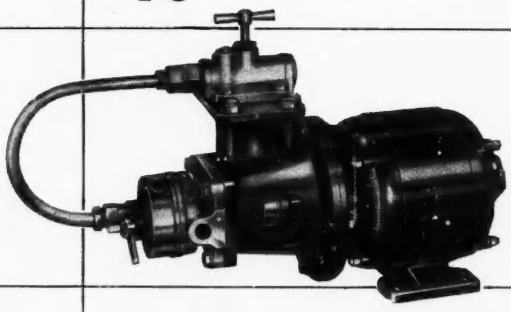

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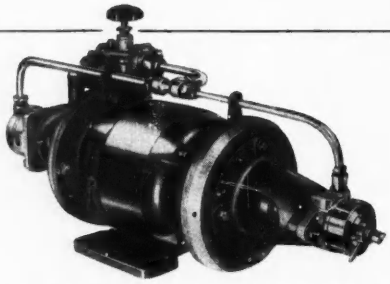

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THE ENGINEERS' DIGEST
REVIEW OF WORLD ENGINEERING PROGRESS
VOL. XVII No. 7 JULY, 1956

New Irradiated-Plastic High-Temperature Dielectric

By J. B. MEIKLE and B. GRAHAM. (From *Electronics, U.S.A.*, Vol. 29, No. 5, May 1956, pp. 146–149, 4 illustrations.)

As is well known, irradiation by high-energy electrons, gamma rays, or neutrons breaks the molecular linkages of many plastics, resulting in a degradation of the material or molecular cross-linking between chains. In the case of a new formulation of polyethylene, the amount of scission caused by radiation is reduced, and cross-linking is increased to develop the thermal stability of the material, resulting in a product which possesses not only the excellent physical and electrical properties of polyethylene, but also the ability to retain them at high temperatures. Now in commercial production, the new material shows excellent promise for use in electronic circuits as a wire and cable insulation, and also as a structural dielectric in components.

In the manufacture of this material, ionizing radiation is provided by an electron-beam generator, employing a resonant transformer to accelerate electrons to 1-MeV peak energy. The output current available for radiation is 1 mA, power output being about 700 W. The beam passes through a titanium window, 2·5 in. in diameter, which must be constantly cooled by a high-velocity air stream. Suitable shielding is provided for absorption of both high-energy electrons and of medium-energy X-rays or bremsstrahlung. In addition, provision is made for removal of the ozone generated by the electron beam.

With an electron accelerator of this type there is the problem of efficient utilization of the beam after its emergence from the window. The beam emerges in a cone, 9 in. in diameter at a distance of 6 in. from the window, and 18 in. in diameter at 1 ft from the window. The maximum density of electron flux is at the axis of the beam, but for efficient operation all electrons, including those in low-density areas at the periphery of the cone, must be utilized. The material being irradiated must be sufficiently thick to stop completely and absorb the energy of the highest-voltage electrons.

The wire with its coating of polyethylene is repeatedly passed between rollers, arranged so that the wire moves entirely across the beam twice, once on top of the rollers and once on the bottom. The wire with its insulation is passed through every intensity level in the beam, and all segments of insulation receive the same integrated radiation dose. The shielding effect of the copper conductor is counteracted by a roller design which twists the wire slowly on its own axis to expose all areas equally. Larger wires move in a figure-8 on the rollers, exposing both sides to radiation. For larger cable jackets, where tangential penetration on the sides is insufficient to irradiate the entire thickness, material of high molecular weight reflects the beam into the jacket sides. The exact radiation dose is not critical ; however, if radiation rates are too high or if cooling is inadequate, the wire covering will become too hot and, where necessary, air is blown over the wire undergoing irradiation for purposes of cooling.

Prior to irradiation, the special polyethylene formulation used possesses the same characteristics as ordinary polyethylenes. Thus, although its electrical characteristics are excellent, it melts at about 100°C. Its volume resistivity is from 10 to 100 times that of most vinyls and 10 times that of polytetrafluoroethylene. Tensile strength is well above that required for wire and cable insulation, and the dielectric constant is between 2·2 and 2·3.

After irradiation, volume resistivity is about 10^{19} ohms per cm^3. When used as a dielectric, this characteristic holds leakage-current loss to low values, even in high-impedance circuits. Dielectric constant is 2·3, comparing favourably with polystyrene (2·5 to 2·7), silicones (3·4 to 9·6), and vinyls (4·0 to 5·0). If the material is formed into a foamed or cellular structure, it acquires a dielectric constant of 1·5 at a density of 0·48. The dielectric constant of 2·3 is maintained up to 150°C.

Whereas plain irradiated polyethylene is usually rated for use up to 120°C, the structure of the new molecular cross-link permits operation at 150°C, and for short periods up to 350°C. In an inert atmosphere, 350°C may be held for sustained periods. If the temperature is raised above 450°C, decomposition may take place, but the resulting products are non-toxic and non-corrosive. If the material is heated by a flame to its ignition point, combustion is sustained. It is hoped that present lines of research will eliminate this problem.

The breakdown voltage necessary to puncture the insulation is approximately 1000 V r.m.s. per mil on 10-mil sections and about 700 V r.m.s. on 45-mil sections.

The electrical and structural properties of the dielectric make it a desirable insulation and jacketing on hook-up wire and cable. The insulation prior to irradiation can be extruded on wire by the usual techniques. This can be done with the plastic either as a solid or foamed, containing discrete cells of inert gas, which reduce the dielectric constant to a minimum of 1·48. This value is a mean between the dielectric constant of 2·3 for the plastic itself and 1·0 for the gas. Depending on the method of extrusion used and the amount of foaming agent added, any intermediate value is obtained.

Following irradiation, an insulated wire can be shielded with a copper braid. The cross-linking of the material resists the normal tendencies of the shield to cut into the dielectric. A jacket of the same or another dielectric can be applied over the shield. If the jacket is of vinyl or regular polyethylene, the operating-temperature range of the cable is limited to that of the dielectric material of the lower temperature rating. The material can be formulated in ten standard colours or can be transparent. For circuit identification, any combination of up to three spiral stripes can be applied.

The finished wire is easily handled in production work. The tensile strength, elongation, and abrasion resistance are equivalent to those of the best vinyl, and the handling and flexibility are approximately equivalent. The insulation is not affected by soldering. During tinning operations the insulation itself can be immersed in the molten

solder without damage. Soldering a lead wire to a shield can be accomplished by dip-soldering, without affecting the dielectric under the shield. The behaviour of the insulation can be compared favourably with that of polyvinyl chloride.

The characteristics of this material adapt it for use with coaxial cable, particularly in high-frequency applications. However, another use is in encapsulation or in sleeving. A sleeving of $\frac{1}{8}$ in. i.d. may be originally extruded with an inside diameter of 0·120 in. Following cooling and irradiation, it may then be distorted to a diameter of 0·200 in. or more, allowing it to be easily slipped in place over the terminal or component to be sleeved. On momentary heating to 135°C, it immediately attempts to return to the 0·120-in. diameter, and, in so doing, it encapsulates the component being sleeved.

In addition, its properties may be varied over a wide range by adjusting the processing prior to forming and by varying the amount of radiation dosage given after forming. The material may have applications for many electrical insulation uses other than wire and cable insulation. Attractive possibilities lie in the field of plastic pipes, since it answers many problems unsolved by other plastics. Pipes made of plastic for hot water, low-pressure steam, hydrocarbon streams, acids, and brines are all within the realm of possibility. Other future applications may include plastic mouldings, film and sheet, extrusions, and shapes.

GERMANY

Gyro-Type Ball Mill

By B. Claus.* (From *Zeitschrift für angewandte Physik*. Vol. 7, No. 2, December 1955, pp. 557–559, 3 illustrations.)

In ball mills and other cylindrical-shell types of mills with internal, freely moving tumbling media, the balls or rods are subjected to a centrifugal force which carries them some distance until their weight predominates and causes them to fall or cataract at an angle onto the coarse product, which they pulverize by attrition. The grinding speed of these mills is limited by the rotational speed of the cylinder; if the limiting value of speed is exceeded, the balls will rotate continuously with the cylinder without cataracting onto the product. Moreover, experience indicates that, in order to obtain a fine product, it is an appreciable advantage to use balls of small diameter. In this respect there is also a limitation, however, because, if the ball diameter is decreased below a certain value, the momentum of the balls will no longer be sufficient for a further reduction of the product.

Various attempts have been made to attain higher grinding speeds by introducing additional movements which tend to prevent the balls from "adhering" to the cylinder wall, e.g., by vibrating the cylinder casing (vibratory mills) or by subjecting the balls to a powerful stream of air (air-swept mills). However, the advantages thus derived are relatively small. The question to be considered, therefore, was whether it would be possible to increase grinding speed substantially by imparting an additional rotary movement to the cylinder in such a manner that this movement would also prevent adhesion of the balls with an effectiveness which would be proportional to the rotational speed of the cylinder. This would then enable high-speed grinding to be carried out and would permit high values of momentum at impact to be reached, even with small balls.

Design Features of the Gyro-Type Ball Mill

The forces to which the balls are subjected in normal cylindrical-shell mills are gravity and centrifugal forces. Further effects could be obtained if Coriolis forces and precessional motion were used. To obtain these it is necessary for the shell to be rotated about a second axis while it is revolving about its normal main axis through the centre of the cylinder, as shown schematically in Fig. 1. In this simple and sturdy design, the cylinder *A* containing the balls and the product to be pulverized is closed by a cover *B* which is attached by means of a bayonet or threaded connection. The cylinder axis *C* is rotatably mounted in a frame *E*. This frame is rotated by a shaft *H*, and the rotary motion of the frame causes a friction wheel *F*, rigidly attached to the cylinder axis, to roll on an annular track *G*. Consequently, the cylinder rotates about its own axis *C*, while at the same time it performs a rotary movement about *H*. At the other end of the cylinder axis *C*, there is another friction wheel *J*, which, however, serves only as a support, being so mounted that it can rotate freely on the cylinder axis. If the two axes of rotation *C* and *H* are at right angles, this free wheel must, of course, have the same diameter as the driving wheel *F*, the wheel diameters being different if the two axes are not perpendicular.

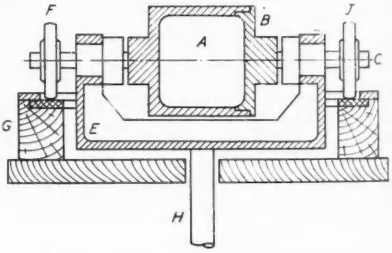

Fig. 1 Section through gyro-type ball mill.

In operation, the cylinder and its charge are subjected to gyroscopic forces owing to simultaneous rotations about two axes. As a result, the grinding media can no longer adhere to the wall during rotation but are displaced, even at the highest rotational speeds. During the motion, some of the balls soon break away from their initial clustering, impinge on other agglomerations, and release other balls; this process continues until finally all the grinding media fly freely in the cylinder at high speed.

Optimum conditions are obtained when the gyroscopic couples have maximum possible values, i.e., with the two axes of rotation *C* and *H* perpendicular, or as nearly so as can be arranged. Moreover, with axes at right angles optimum mechanical stability of the system is also maintained.

(*Concluded on page 304*)

* Preliminary details of the mill described in this article by Claus, of the Photographic Institute, Kgl. Tekniska Högskolan, Stockholm, were given in The Blue Pages, June 1956, page 221. Ed., E.D.

The Surface Finish of Fine-Machined Gear-Tooth Flanks

By W. HAGEN. (From *VDI-Zeitschrift*, Vol. 98, No. 8, March 11, 1956, pp. 319–328, 45 illustrations.)

The finish of ground teeth is dictated by the grinding feed and the material of the grinding wheel and workpiece ; finish-grinding without further feed improves the surface. In the shaving of gears the mesh of tool and workpiece, and the feed and the material of the workpiece, influence finish. Cold-rolling, lapping, and diagonal hobbing also result in good surfaces.

THE tooth errors of precision gears are generally examined with mechanical measuring instruments, but the surface smoothness which influences these measurements usually is either not considered or is only estimated visually or by touch. Such estimates are extremely inaccurate, even if effected by experts ; for instance, a rough but bright surface is judged to be better than a smoother but matt surface. The film-replica method, however, permits measurement of surface finish and has already been applied successfully to a number of large gears of up to 15 ft in diameter, generated by shaping or hobbing [1]; the roughness observed was often surprisingly large and depended mainly on the method of generation and the wear of the tool. The present investigation deals with the surface finish of fine-machined, i.e., ground or shaved, tooth flanks of smaller gears, such as those in automobiles.

Only a small number of larger gears was examined. The replica method was used in combination with optical instruments, i.e., the Schmaltz sectional microscope and the Zehender interference microscope with immersion chamber[2]. The latter method is especially suitable, as it does not require contact with the replica and also gives a qualitative estimate of a whole area of the tooth flank[3].

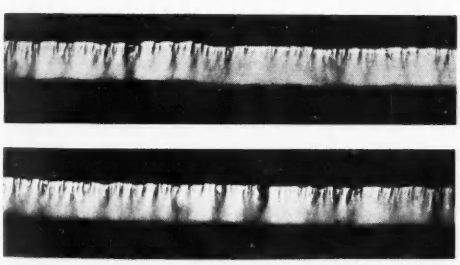

Fig. 1. **Optical section taken from the actual surface of a tooth flank of hardened Cr-Mn steel. Surface finish 3 to 7 μ.**

The sectional microscope indicates the height of asperities by making the differences in height of the observed section appear white in the photograph, as in Fig. 1. The factor of obliquity $\sqrt{2}$ and the magnification must be considered in establishing the scale, which in this photograph is 1 mm depth of section for asperities of 5 μ. The total length of each section corresponds to 0·56 mm of the actual tooth flank. Interference photographs, on the other hand, give contour lines with a distance between lines depending on the wavelength of the light used and on the immersion liquid. All the following photographs reproduce an area of 0·55 × 0·37 mm on the tooth flank and, with the exception of Fig. 2, have been taken with replicas immersed in oil ; the distance between lines represents a 3-μ difference in elevation, and the height of asperities is found by counting the number of linear distances by which an interference line is displaced. Fig. 2 is an interference photograph of a micrometer scale and has been taken with the same adjustment of the microscope as the other illustrations, so that width and breadth of, for instance, a scratch-mark can be determined from the interference photographs.

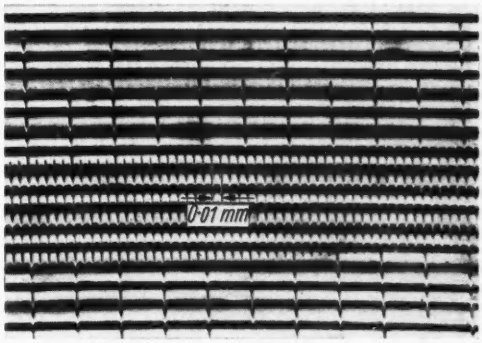

Fig. 2. **Interference photograph of a micrometer scale.**

The precision gears used, most of them for automobiles, had diameters varying from 18 to 4300 mm and modules varying from 2 to 8 mm. Usually, five to ten replicas, 25 × 30 mm in size, were taken from different tooth flanks irregularly distributed over each gear. The finish was determined on at least ten different places of each replica, and a number of photographs was taken. Thus, 50 to 200 measuring values for the finish of any one gear were obtained for establishing an average. Even though the surface roughness of fine-machined gears in general does not vary as much as that of generated gears, the finish is by no means uniform, and it requires a considerable effort to obtain a uniform smoothness. Comparison has shown that the finish depends less on the machining process than on other influences, e.g., the feed of the cutter. The wear of the tool is very small in fine-machining processes and hardly enters into consideration, so that machining conditions can be varied within wide limits and the surface finish changed accordingly. However, experience is insufficient for a prediction of surface finish obtainable from given machining conditions ; nevertheless, a few conclusions regarding the finish to be expected, especially for ground gears, may be drawn from the results given here. The illustrations reproduce average finishes, unless otherwise indicated. The present investigation is mainly concerned with ground or shaved gears, other machining processes being studied only for the purpose of comparison.

GROUND TOOTH FLANKS

(a) *Grinding Process Resulting in a Cross-Cut Pattern:—*

Fig. 1 shows optical sections of a ground tooth flank, while Figs. 3 and 4 are interference photographs of a well-ground and a coarsely ground tooth flank. The influence of tool feed was investigated on two mass-produced gears of case-hardened Cr-Mn steel ; the surface roughness was 2 to 4 μ for normal feed, and 3 to 5 μ with a feed nearly doubled, i.e., the finish improved with decreasing feed, as expected. It can be improved further by several traverses during finish-grinding ; doubling the number of traverses in one case reduced the roughness from a level between 2 and 5 μ to between 2 and 3·5 μ. A master

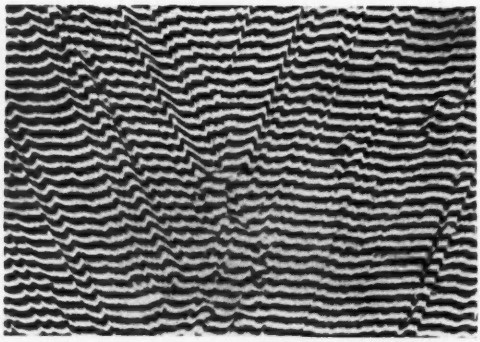

Fig. 3. Cross-ground straight spur-tooth flank of a lorry transmission gear of hardened Cr-Mn steel. Finish 2 to 4 μ, except for a few scratches up to 8 μ.

gear with particularly well-ground flanks showed a roughness of 1 to 3 μ only. For a quantitative determination of roughness, the interference lines must here be normal to the direction of the grooves to be evaluated (Fig. 4), but a satisfactory estimate can be made if the lines are normal to the bisector of the two grinding directions (Fig. 3), which shows the cross-pattern and faulty regions especially clearly.

(b) "*Hob-Grinding*" *Process with a Double-Conical Wheel*:—

This process in general gives very uniform surfaces of the flanks and, with suitable machining conditions, also gives a good finish. A production finish obtained with a case-hardened Cr-Mn steel on a new grinding machine gave 2 to 5 μ. Fig. 5 shows a roughness of 1 to 3 μ obtained by this process.

The flanks of a carefully ground master gear in the used condition showed a finish of 0·2 to 0·5 μ; replicas of this quality should be evaluated, not under oil but in air (Fig. 6).

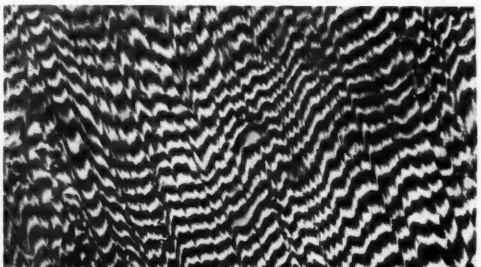

Fig. 4. Cross-ground helical spur-tooth flank of a tractor transmission gear of hardened Cr-Mn steel. Finish 5 to 12 μ.

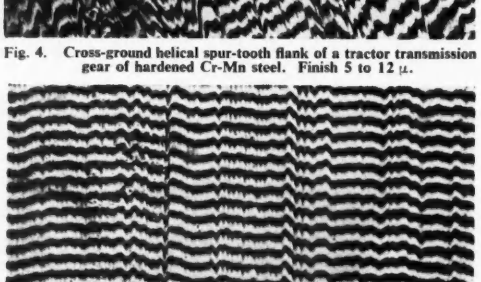

Fig. 5. "Hob-ground" helical spur-tooth flank of hardened Cr-Mn steel. Finish 1 to 3 μ.

Shaved Tooth Flanks

The surface finish in this case varies widely. For instance, random tests taken from current production in a well-equipped factory gave 3 to 7 μ after shaving (Fig. 7). In contrast with ground gears, these gears are

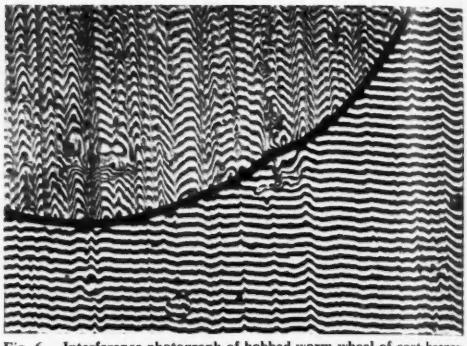

Fig. 6. Interference photograph of hobbed worm wheel of cast bronze, with finish of 1 to 2 μ.
The lower portion shows the replica immersed in oil, with a line distance representing 3 μ; the portion above the thick line shows the replica in air, with a line distance representing 0·53 μ.

Fig. 7. Helical spur-tooth flank of Cr-Mn steel, as-shaved, unhardened. Finish 3 to 7 μ.

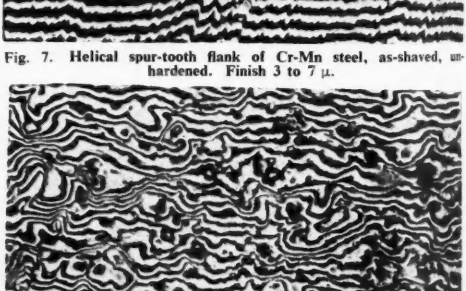

Fig. 8. Shaved helical spur-tooth flank after hardening, ready to be fitted. Finish 12 μ and over.

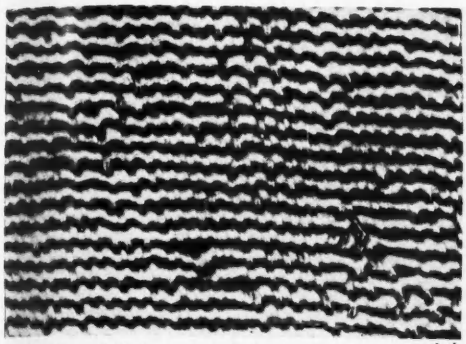

Fig. 9. Shaved helical spur-tooth flank, smoothed with emery cloth after hardening. Finish 2 to 6 μ.

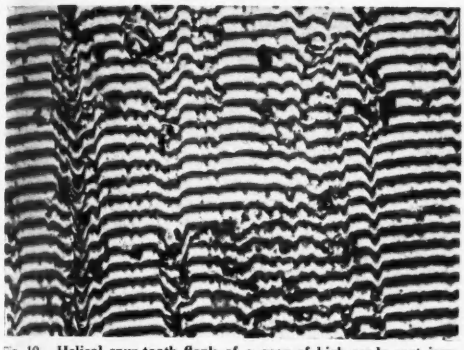

Fig. 10. Helical spur-tooth flank of a gear of high-grade cast iron. Finish 2 to 6 μ; numerous nests of graphite flakes.

mostly case-hardened after finish-machining, and the scale formed by heat treatment cannot be removed entirely, as may be seen under the microscope, even where the flank appears clean to the naked eye. Fig. 8 shows the hardened gear as fitted into a transmission ; the finish appears irregularly coarse, with scratch depths greater than 12 μ. The evaluation of such surfaces is very difficult. Probably, the oxide layer soon disappears on running in, and this state has been simulated by careful manual smoothing of the flanks with fine emery cloth. The surface (Fig. 9) then showed 2 to 6 μ, i.e., a slight but probably incidental improvement on the as-shaved condition.

The conditions of mesh between cutter and workpiece influence very considerably surface finish, so that there exists a limit for satisfactory shaving which may be altered by a change in meshing conditions, e.g., by a change in the overlap ratio. When the cutter presses more than it cuts, deep scratches in the direction of cutter motion appear on the flank. On a pinion of a case-hardened Cr-Ni steel, the flanks showed 3 to 5 μ near the tip, 6 to 9 μ at the centre, and 10 to 20 μ near the root. Whereas the flank near the tip is still satisfactory, the deteriorating conditions of mesh yield an increasingly coarser surface towards the root.

The cutter feed also influences finish. A normal production feed gave 2 to 3 μ with scratches up to 5 μ ; doubling the feed led to an improvement (1 to 3 μ), whereas a relatively high feed again appreciably reduced the quality of the finish (3 to 8 μ, with scratches up to 15 μ). Such high shaving feeds are sometimes used when a grinding operation is to follow.

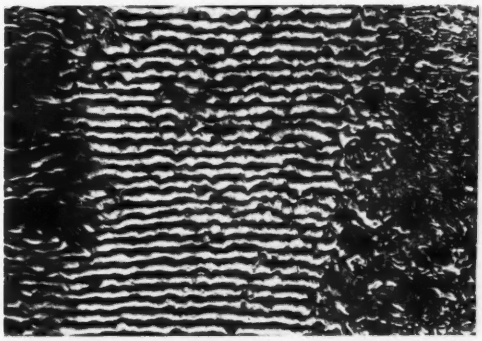

Fig. 11. Helical spur-tooth flank of a fibre gear. Finish 2 to 4 μ, measurable only between the deeper points of the surface.

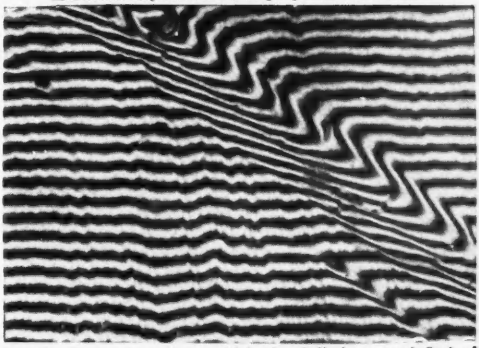

Fig. 12. Traces of previous machining in a helical spur-tooth flank of Cr-Mn steel. Finish 8 μ.

The influence of the material of the workpiece was investigated on gears of various steels, of high-grade cast iron (Fig. 10), and of hard fibre (Fig. 11), all mass-produced at the same factory. Some results are given in Table I.

TABLE I : INFLUENCE OF WORKPIECE MATERIAL ON FINISH

Material	Gear	Finish
0·45% C steel	36 teeth, 3 mm module, 23-deg. helix	1 to 3μ
High-grade cast iron	19 teeth, 3 mm module, 30-deg. helix	2 to 6μ
0·18% C, 2% Cr, 2%Ni steel	23 teeth, 4·75 mm module, 18-deg. helix	3 to 7μ, with spots of 15μ and over
0·16% C, 1·2% Mn, 1% Cr case-hardening steel	29 teeth, 3·5 mm module, 27-deg. helix	3 to 8μ
Hard fibre ("Novotex")	38 teeth, 3 mm module, 30-deg. helix	2 to 4μ

The state of wear of the cutter is also important. New or reground cutters shave coarser flanks than cutters which have already machined about 100 gears of average dimensions. Worn cutters, on the other hand, press more than they cut, so that the flanks are non-uniform, and very smooth regions are found adjacent to very deep scratches where the material has been sheared. Finally, traces of previous machining, if too coarse, are often found after shaving ; these are easily recognized when the direction of previous machining differs from that of shaving, as in Fig. 12, where the shaving marks are perpendicular to the interference lines, and those of previous machining oblique.

Comparison with Other Finishing Processes

Pressure-polished tooth flanks (Bolender method) show a very smooth finish wherever the pressure has been applied fully. However, considerable traces of previous machining remain ; on almost every tooth flank rough areas alternate with smooth areas, and even these still show traces of previous machining (Fig. 13). Lapping produces very good surfaces ; for instance, a worm wheel of cast bronze (12 Sn, 88 Cu), hobbed to a finish between 4 and 8 μ, showed after lapping a transverse finish of 0·5 to 1·5 μ (Fig. 14), and a finish of less than 0·5 μ in the direction of lapping (Fig. 15). A special choice of machining conditions in hobbing may also result in a very high surface finish, as shown by the interference photograph (Fig. 6) of a worm wheel finish-machined with a carefully ground hob. The diagonal-hobbing method[4] in particular improves surface finish because, owing to the axial shifting of the hob during this process, the wear of the tool is distributed over several pitches and is therefore less severe. Comparison of two gears of a 0·6 C steel, generated with the same hob on the same machine tool, showed a finish of 12 to 15 μ after ordinary hobbing (Fig. 16), and of 2 to 3 μ with scratches up to 5 μ in depth, after diagonal hobbing (Fig. 17).

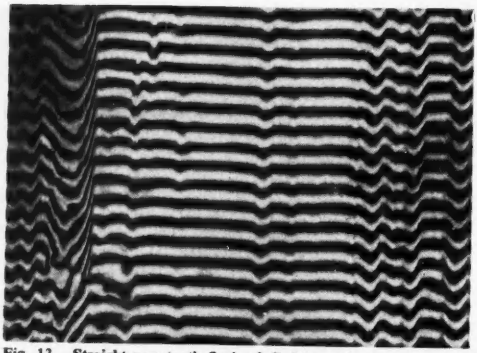

Fig. 13. Straight spur-tooth flank of Cr-Mn steel, pressure-polished after generating. Generated finish of 9 to 13 μ still visible at the sides, which were not touched by pressure-polishing. Finish of polished parts below 1 μ.

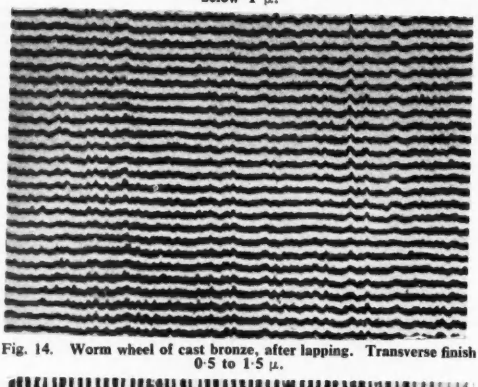

Fig. 14. Worm wheel of cast bronze, after lapping. Transverse finish 0·5 to 1·5 μ.

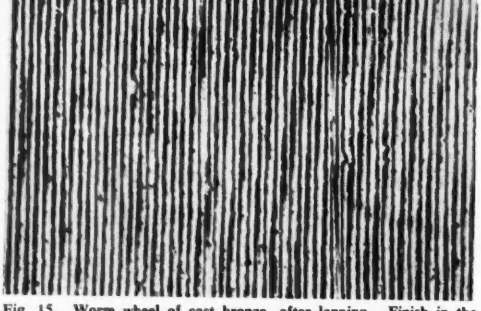

Fig. 15. Worm wheel of cast bronze, after lapping. Finish in the direction of lapping <0·5 μ.

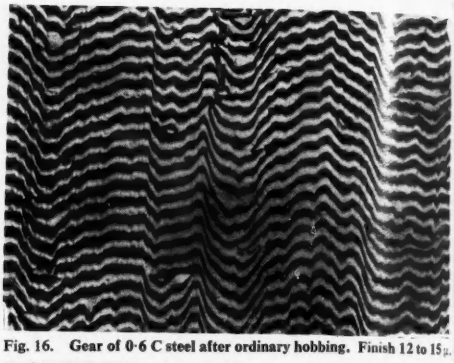

Fig. 16. Gear of 0·6 C steel after ordinary hobbing. Finish 12 to 15 μ.

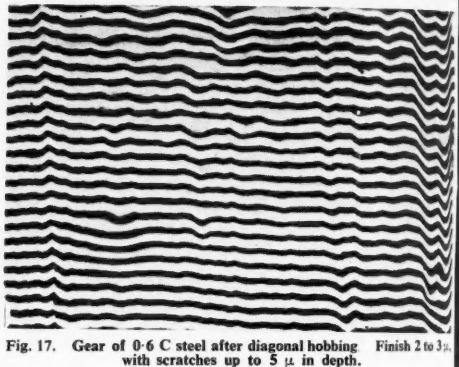

Fig. 17. Gear of 0·6 C steel after diagonal hobbing with scratches up to 5 μ in depth. Finish 2 to 3 μ.

Conclusions

Comparisons of fine-machined with generated tooth flanks shows that fine-machining does not necessarily lead to a better surface finish. The quality of the finish depends essentially on machining conditions ; detailed relations remain to be investigated. However, as long as these relations have not been established, experience and observation will be the only guides to better surface finishes. Nevertheless, only a hob-ground finish can be judged with any degree of reliability by the naked eye. Even with long experience, the flank surface of gears finished by other methods cannot be estimated reliably, as brightness, colour, and lighting impair judgment. Hence, numerous quantitative measurements will be required to find how machining conditions influence the surface finish of tooth flanks.

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Contactless High-Frequency Electric Mine-Haulage Systems

By N. A. Staroskolsky, F. I. Bakhmutsky, B. G. Kemenetsky, and V. E. Rosenfeld.

(From *Elektrichestvo*, No. 4, April 1956, pp. 28–31, 5 illustrations.)

New prospects of solving the problem of electric haulage in mines which are inherently dangerous because of firedamp and dust are opened up by the use of contactless high-frequency electric haulage systems. Development of this type of underground transport, carried out by the Donetz Scientific Research Mining Institute and the Molotov Mining Machinery Works, has led to the conclusion that modern methods of generating high frequencies, coupled with the design of suitable rectifiers and condensers, have made the contactless electric locomotive superior to the battery-operated type of mine-locomotive.

Fig. 1 shows the diagrammatic layout of the power supply in the contactless electric system, in which an electro-mechanical high-frequency generator G supplies a traction network consisting of two insulated cables suspended at a height of between 1·6 and 1·8 m above the top of the track. The magnitude of the current in the circuit is automatically kept almost constant and independent of the tractive load. Automatic reduction of circuit current during those periods when the locomotive is not in operation can also be achieved. Condensers C_L are installed at distances apart of from 500 to 600 m, and the total capacitive resistance of these condensers, together with that of the condenser C_A connected in parallel with the generator, is selected so as to be equal to the inductive resistance of the network. Consequently, the generator winding carries active current only.

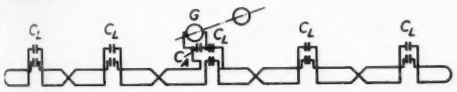

Fig. 1. **General arrangement of the power-supply lines for the contactless mine-haulage system.**

The locomotive incorporates a flat power receiver P (Fig. 2), which consists of several turns of a special cable and which can be designed with or without an iron core. To compensate the inductive resistance of the receiver winding, a battery of condensers C_P is installed in the locomotive and, in order to reduce the maximum voltage between the elements of the circuit, the winding of the power receiver P, as well as the battery of condensers C_P, is divided into sections connected in series.

Under mine conditions, the most appropriate frequency is of the order of 4000 to 5000 cps. At such a frequency, quite considerable difficulties are encountered in the design of traction motors for alternating current. At the same time, however, rectification of current of this frequency presents no special difficulties ; consequently, it is convenient to apply d.c. traction motors to contactless locomotives.

The operation of traction motors in the high-frequency locomotive is distinguished by a fluctuating voltage at the motor terminals. With small loads this voltage is near that of the open circuit of the rectifier, but with large loads it is substantially lower, owing to the voltage drop in the power circuit of the locomotive and in the rectifier. The voltage drop in the power circuit is caused essentially by the active resistance of the power-receiver winding, and by the eddy currents in the body of the locomotive and in the steel roof-supports of the mine haulage-way.

The traction characteristic of the high-frequency electric locomotive is less positive than that of the battery locomotive, if traction motors with series excitation are used. A somewhat more positive characteristic can be obtained by using traction motors M_1 and M_2 with compound excitation E_1 and E_2 (Fig. 2). For this installation selenium rectifiers are suitable. These rectifiers must withstand an appreciable reverse voltage (not less than 40 to 50 V), because otherwise the large number of rectifier elements connected in series will considerably reduce the power of the locomotive, with an adverse effect on its traction characteristic. The condensers C_P, which serve for the reduction of the reverse-voltage peaks and for the increase of the maximum power supplied by the rectifier S, are connected to the rectifier output terminals.

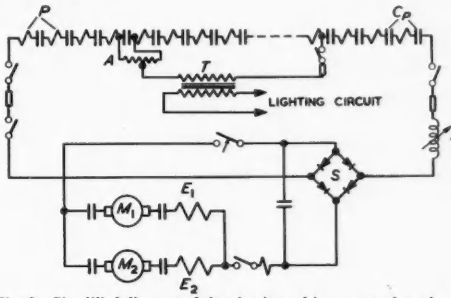

Fig. 2. **Simplified diagram of the circuit used in a contactless electric mine-locomotive.**

In order to obtain the necessary power for the locomotive and an acceptable haulage efficiency, and also to ensure reliable service under mine conditions, condensers with a low loss-angle δ are essential for the locomotive, the transformer stations, and the line compensating points. Polystyrene condensers with a tan δ value of about 0·0008 have been found most suitable.

The traction motors M_1 and M_2 in the locomotive develop their maximum power when in resonance with the power circuit, comprising the inductivity of the winding of the power receiver P, the capacity of the battery of condensers C_P, and the capacity of the rectifier S with the motors in circuit. To start the locomotive and to control its speed, it is necessary to remove the circuit from the resonant condition, and this can be achieved by a change in the capacity of the battery of condensers C_P or by means of a choke K of variable inductance.

High-frequency current is also used for lighting purposes. The locomotive searchlight bulbs cannot, however, be connected to the input (or output) of the selenium rectifier, owing to the large voltage fluctuations incurred in starting and when controlling the speed of the locomotive. It is also difficult to use a separate receiver for the lighting circuit, as this would induce not only a rather small e.m.f. from the line current, but also a much larger varying e.m.f. from the current in the power-receiver winding.

The lighting circuit for the locomotive is connected at two points in the power circuit, equality of the inductive and capacitive voltage drops along the tapped section of the circuit being achieved by means of an autotransformer A, as shown in Fig. 2. A separate transformer T isolates the lighting circuit from the high voltage which arises in the power circuit during short-circuit conditions and

overloads. During operation of the locomotive, voltage fluctuations in the power-receiver winding are inevitable and are caused by differences in the height of suspension of the cable, by swaying of the locomotive on the track, and by current fluctuations in the line. For this reason the lighting circuit incorporates a ferromagnetic voltage stabilizer.

The first contactless mine-locomotive in the U.S.S.R. was operated in 1951 on a frequency of 2500 cps over an experimental narrow-gauge surface branch-line of the Donetz Scientific Research Institute. This installation contained many design features which subsequently had to be modified. In 1954 a contactless locomotive was put into service over a stretch of underground track. One of the two locomotives built had polystyrene condensers and therefore yielded a higher power than the other locomotive, which had oil-impregnated paper condensers.

Insofar as the power of the contactless locomotive is concerned, experiments have shown that, with a line current of 200 A and a distance of 75 mm between the power-receiver winding and the line cables, and using timbered roof-supports, the power supplied to the traction motor was of the order of 14 kW. Furthermore, experiments and analysis have shown the optimum frequency under mine conditions to be about 4000 cps. In this connection, comparisons of the characteristics of a 4000-cps contactless mine-locomotive and a battery-type mine-locomotive, at the same voltage and with timbered roof-supports, show that, for a 1-hr. rating, both locomotives develop the same power, i.e., about 17 kW. At lower frequencies, however, a higher voltage must be applied to the motors of contactless locomotives than to the motors of battery-operated locomotives for the same power output. With metal roof-supports, it was found that the power of the contactless locomotive exceeds that of the battery locomotive only with small and medium currents. In addition, it was established empirically that, with sonic current frequencies, the surrounding rock had no noticeable effect either on the power of the contactless locomotive or on line losses.

The capital investment per locomotive is greater in the case of contactless haulage than in battery haulage when traffic density is low. With a high traffic density, however, the investment for contactless traction is less than for battery traction. The operating costs are always lower with contactless traction.

It is considered that the use of contactless locomotives with a drawbar pull of 8 tons is economically practicable when at least two or three locomotives are used over short lengths of track (between 1·5 and 2 km), and three or four locomotives over longer lengths (between 4 and 5 km).

The efficiency of contactless mine haulage is somewhat lower than the usually accepted figure for battery-locomotive haulage. Haulage efficiency depends on traffic density. With timbered roof-supports and where from 1·4 to 2·0 contactless locomotives are required to operate per kilometre of track, the efficiency with a 4000-cps system is between 23 and 30%. With 0·6 to 1·3 contactless locomotives per kilometre of track, efficiency is reduced to between 18 and 25%, despite the use of automatic switchgear for cutting out unused sections of the track. Where the roof-supports are of metal, instead of timber, the above efficiency values are reduced by about 10%.

The application of contactless haulage requires a larger investment of non-ferrous metals, particularly of copper for the special cables, which comprise an insulating sheath of 35 mm o.d., and eighteen individual conductors, each consisting of nineteen copper wires of 0·63 mm diameter, arranged around a core of 1·8 mm in diameter. The initial outlay for non-ferrous metals for each locomotive is greater in contactless transport than in battery transport by between 500 and 1000 kg, but annual replacement is less by between 40 and 50 kg.

The safety problems involved in contactless mine-haulage systems are of the greatest importance. While it is true that the possibility of providing non-sparking power transmission to a moving locomotive constitutes a great advance in ensuring safety in mines, there is always the possibility that the high-frequency electromagnetic field created around the line cables might transmit electrical energy not only to the locomotives but also to every conductive material in its radius of action. An analogous effect is produced by the power receiver in the locomotive, and the induced currents might well prove to be dangerous under certain conditions, from the point of view of ignition of fire-damp or of dust. As a result, a number of aspects of the safety of the contactless mine-haulage system was investigated, including the questions of injury to personnel by high-frequency currents and the adverse physiological effects of the electromagnetic field, the sparking of subsidiary conductors, the heating up of metallic bodies and the possibility of ignition of combustible materials, and the possibility of premature exploding of the electrically fired detonators used for blasting operations.

Extensive investigations of these aspects of safety have shown that the maximum e.m.f. which can possibly be induced in extraneous conductors is about 40 V, and it is known from experimental observations that currents of sonic frequency have no lethal or adverse physiological effects on human beings at voltages below 40 V. Furthermore, with regard to the sparking hazard, experiments with a specially selected cable channel in close proximity to the contactless network, and so arranged that the plane of the channel was parallel to that of the line, have indicated that sparking which might well be dangerous from the point of view of ignition of fire-damp,, etc. may arise. However, the occurrence of such channels in an actual mine is quite improbable. The circuits formed by the track, the conduits, and the cables can be made virtually non-sparking by the simple expedient of crossing the cables of the contactless network at intervals of about 60 to 70 m, and by earthing at similar intervals the conductors concerned. In the case of metal roof-supports, dangerous currents arise only during the passage of the locomotive, but dangerous sparking occurs only when such metal supports are seriously cracked. The magnitude of the sparking current rises with increased frequency.

With regard to the safety aspects of the power receiver, it was found that, where a receiver with an iron core was used, the distance between the overhead cables can be reduced to between 350 and 400 mm, as compared with the 600 mm between cables normally required for a receiver without an iron core. By using an iron core, then, the currents induced by the line field in extraneous conductors are considerably lower, as also are those induced by the receiver field, with consequently less danger of sparking.

Experiments have shown that the contactless network cannot cause appreciable heating of any metallic objects, even when they are in the vicinity of the cables. Moreover, it is definitely established that electric detonators can be carried in contactless mine-haulage systems with complete safety. Incidentally, unless filters are used, the contactless network has been found to produce powerful interference in telephone lines laid along the haulage-way.

Thermodynamic Aspects of Nuclear Power Stations

By L. HELLER. (From *Acta Technica, Academiae Scientarum Hungaricae*, Vol. 14, Nos. 1–2, 1956, pp. 137–164, 16 illustrations.)

Although it is evident that great efforts have been made to make atomic power stations as economical as possible, it is also clear that these efforts have been applied almost exclusively to the development of the reactor itself. Very few contributions have been directed to the construction of the power conversion system, and since the latter decisively affects the economy of the entire power station, this article is intended to deal with the problem from the point of view of heat engineers.

WHILE, in conventional thermal power stations, higher efficiency is obtainable only at the expense of an increase in investment per unit capacity, in nuclear power stations improvement of the efficiency of the power-conversion system reduces almost linearly the total investment per kilowatt of available power. With a given reactor, depending on whether the heat from the reactor coolant is utilized with higher or lower efficiency, the electrical power obtained in the power-conversion system will accordingly be increased or decreased, while the cost of construction of the reactor will, of course, remain unchanged.

This statement is in disagreement with the general opinion found in the literature to the effect that thermal efficiency has virtually no importance where fuel costs are low, as can be expected from nuclear power stations in the course of eventual development. However, this point of view is tenable only in conventional power-engineering practice, where even a moderate increase in efficiency involves a very considerable increase in investment per kilowatt. The case is quite different if the increase in efficiency no longer affects the most important part of the investment. Here, independent of the total fuel costs per kilowatt-hour, the capacity of the power station and the electrical units produced per year will increase proportionally with efficiency, while the cost of the units produced will be reduced in virtually the same proportion, with investment and annual fuel costs remaining constant. This is the case, of course, not only with nuclear power plants but also with hydro-electric power schemes.

Boosting the thermal efficiency of the nuclear power station is thus, for the heat engineer, a task of much greater importance than it is in conventional thermal power stations, because the attainment of high thermal efficiency makes the nuclear power plant a source of energy more economical than others so far available. The importance of the problem of thermal efficiency is further enhanced by the fact that the facilities for attaining high efficiency in nuclear power stations are much more limited than in coal-burning power plants. Thus, difficulties of a nucleo-physical nature and of material properties do not at present permit the temperature of the reactor coolant to be raised above 300 to 350°C—a great handicap in developing high thermal efficiency.[1,2,3,4]

Even if in the course of development the temperature, as is likely, will be raised, the nuclear power plant will always be at a disadvantage in this respect, compared with conventional thermal power stations. As regards constructional materials, in addition to their heat-resisting qualities, other requirements of a nucleo-physical nature will also be of importance, and the maximum permissible temperature in nuclear power stations will always remain below that permitted in conventional stations. Thermal efficiency is thus of decisive importance in nuclear power stations.

When considering efficiency, the temperature conditions of the reactor coolant must be taken as a starting point, i.e., the maximum theoretical work obtainable at limiting temperatures of the coolant must be taken into account. If only the cycle of the working medium is examined, this can easily give misleading results when assessing ultimate efficiency. Literature on the subject [1,2] shows that some designers have found that, at the very low temperature of the coolant, a turbine operating on saturated steam is most satisfactory when used in conjunction with multi-stage feed-heating, as a result of which the efficiency of the saturated steam cycle approaches that of the ideal Carnot cycle. This reasoning is, however, misleading, inasmuch as it may tend to make designers believe that maximum efficiency will be obtained by approaching the Carnot cycle—an incorrect conclusion in this case. This solution approaches perfect reversibility only in the working medium, but disregards (even assuming infinitely large heat-exchange surfaces) the irreversibility of the process taking place at the same time in the heat exchanger. It is evident that the two processes cannot be separated, and a minimum degree of irreversibility should be the aim in the entire process. The Carnot efficiency attained in the steam power plant itself is useless if, at the same time, there is a maximum degree of irreversibility in the heat exchanger.

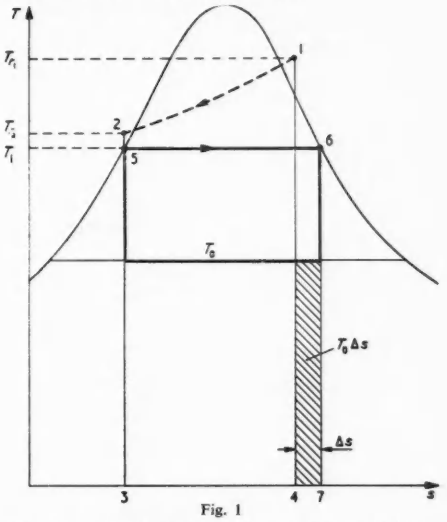

Fig. 1

Fig. 1 clearly illustrates the incorrectness of the current view. If all changes of state taking place in the entire power station are plotted in the *T-s* diagram, it is clear that, although the steam cycle takes place in principle without an increase in entropy, the increase in entropy in the heat exchanger is responsible for substantial losses. If it is assumed that the temperature of the reactor coolant in the heat exchanger drops from T_{r_1} to T_{r_2}, then the amount of heat transferred is proportional to area 1,2,3,4. Simultaneously, the amount of heat extracted by the

working medium is proportional to area 5,6,7,3 and, as a consequence of the equality of the two amounts of heat, an increase in entropy takes place through heat transfer at finite temperature differences. If the increase in entropy is Δs and the condensing temperature of the steam cycle is T_0, the work thus lost is $T_0\Delta s$, i.e., it is proportional to the hatched area in Fig. 1. Hence, the perfect reversibility of the steam cycle is useless, if heat exchange takes place irreversibly.

The ideal solution at the permissible upper temperature limit in the reactor would be, of course, the approximation of isothermal heat transfer, which, however, is conceivable only with vapour generation in the reactor itself. To use steam for this purpose would involve several difficulties; thus, for instance, it would necessitate the application of high pressures in the reactor; furthermore, water vapour dissociates even at low temperatures under the effects of radioactivity. Mercury vapour appears to be far more suitable for the above purpose; with mercury vapour, the necessary pressure is very low, and circulation in a closed system between the reactor and heat exchanger can be effected without the use of pumps, i.e., by gravity, with a small head because of the high specific gravity of mercury. Naturally, however, the problems of radioactivity, etc. would still arise. Fig. 2 shows the T-s diagram corresponding to isothermal heat transfer.

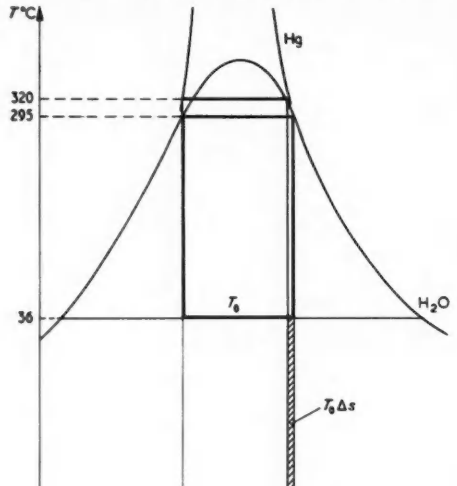

Fig. 2

If, according to Fig. 1, the permissible upper temperature limit in the reactor is $T_{r_1} = 320°C$, and the temperature after the heat exchanger is $T_{r_2} = 220°C$, and at the same time the heat exchanger is proportioned to evaporate the water serving as the working medium at $T_1 = 215°C$ (488°K), the ideal efficiency of the saturated steam cycle, assuming a condensing temperature T_0 of 36°C (309°K), will be

$$\eta = (T_1 - T_0)/T_1 = 0{\cdot}367$$

Similarly, if a temperature of 320°C is chosen as the upper limit in the reactor, then, in the case of isothermal heat transfer, mercury vapour condensing in the heat exchanger at 320°C evaporates the water serving as the

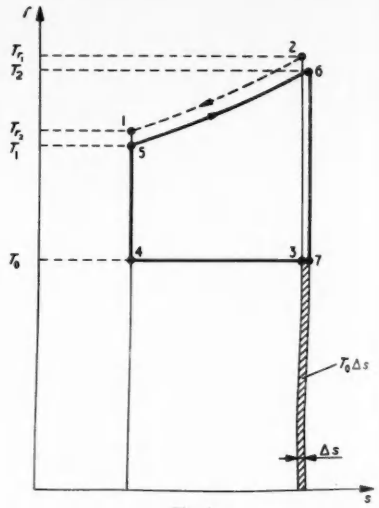

Fig. 3

working medium at 295°C, assuming that a heat exchanger of the same surface as that in Fig. 1 is used and that account is taken of the better coefficient of heat transfer. Because of the smaller temperature differential in the heat exchanger, as well as the higher average temperature of heat introduction, the degree of entropy increase will be lower, and the loss area $T_0\Delta s$ will also be smaller. The efficiency of the steam cycle will accordingly be higher, because the upper temperature limit of the Carnot cycle will be 568°K, instead of the former 488°K. With these values, the efficiency η becomes 0·456.

The efficiency thus derived gives the theoretical maximum value at a given upper temperature limit (in this case 320°C) and for a given heat-exchange surface, this value being about 24% higher than in the case of Fig. 1. In actual fact, the improvement will be even greater, because the optimum heat-exchange surface in the case of isothermal heat transfer will certainly be larger, and consequently the temperature differential will be reduced and the upper temperature limit of the steam cycle will accordingly be further increased.

If it is considered that mercury is not a suitable heat-transfer medium because of its nucleo-physical properties, then other materials must be sought, not only with adequate nucleo-physical qualities, but also with thermal and physical properties most nearly approximating those of mercury.

Until practical facilities for isothermal heat transfer become available, such thermodynamic solutions must be aimed at assuring minimum irreversibility of the whole system. This means that entirely new methods of construction of power-conversion systems must be sought and, as already indicated, the classical steam cycle must be abandoned. An analysis of the problem in the T-s diagram in Fig. 3 shows that, in the case of application of a liquid or a gas as the heat-transfer medium, perfect reversibility, or the possibility of extraction of the maximum theoretical work, is approachable only if, in the course of heat exchange, the temperature of the working fluid also changes, i.e., rises continuously. In this instance, compared with the theoretically recoverable maximum work (area 1,2,3,4), work proportional to area 5, 6, 7, 4 can be extracted, and this is now less than the theoretical maximum only by the likewise much smaller

$T_0 \Delta s$ area, resulting from irreversibility in consequence of heat exchange at a smaller difference of temperature. Since a finite temperature difference cannot be eliminated in practice, the magnitude of the loss depends on the smallest temperature differential possible, or on the practicable size of the heat-exchange surface. It is therefore evident that the application of the classical steam cycle must be abandoned in the case of nuclear power stations.

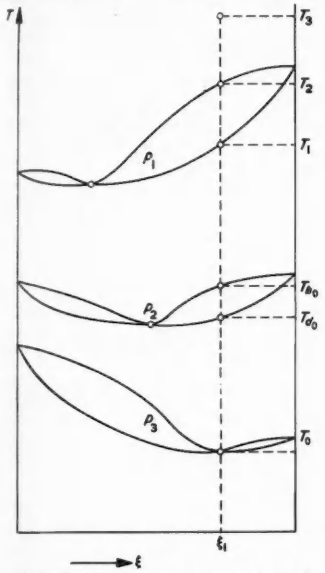

Fig. 4

If potential new systems are investigated, the use of some suitable binary azeotropic mixture as a working medium offers interesting possibilities. Such a system can be most economically developed if the binary medium has an adequate azeotropic point insofar as thermal build-up is concerned. The temperature/mixture-ratio diagram (T-ξ diagram) of a binary medium with azeotropic properties is shown in Fig. 4, in which the area enclosed by the curves of boiling points and dew points pertaining to different pressures gives the evaporation area at the corresponding pressure. Examination of this diagram shows that, by the use of such a fluid as the working medium, ideal conditions can best be approached. Evaporation of this medium at constant pressure takes place, not at constant, but at continuously increasing, temperature; subsequently, superheating is also effected at a continuously increasing temperature. In the course of evaporation the temperature of the medium rises from T_1 to T_2, and during superheating it increases from T_2 to T_3. If p_3 denotes the condensation pressure of the process, then at a value ξ_1 chosen in Fig. 4 the change of state of condensation coincides with the azeotropic point; in other words, heat extraction in the condenser takes place at a constant temperature, i.e., at the condensing temperature T_0.

With a binary azeotropic mixture as the medium, evaporation takes place at constant pressure but at increasing temperature, whereas condensation after expansion is effected at constant temperature. Evaporation at increasing temperature ensures minimum irreversibility in the heat exchanger, while condensation at constant temperature makes possible isothermal heat extraction at the lower temperature.

The suggestion has been made [5] to apply such a system to waste-heat utilization, in which case heating of the condensate of the working medium from a temperature T_0 to T_1 is also effected by further cooling down of the waste-heat transfer medium. This process presents no difficulty in conventional waste-heat recovery, but its application to nuclear power stations obliges certain modifications. In the heat exchanger, only that amount of heat necessary for evaporation and superheating of the working medium is extracted, i.e., the amount required for heating from a temperature T_1 to T_3 (the reactor coolant thus leaves the heat exchanger at a temperature exceeding T_1 by a value corresponding to the temperature differential), while preheating of the working fluid from a temperature T_0 to T_1 is effected by approaching the ideal Carnot efficiency, which can be obtained by very simple means. While in steam cycles regenerative feed-heating permits a good approach to the ideal Carnot efficiency only if an infinitely large number of extraction stages is used, with the binary azeotropic mixture as the medium this can be executed with a finite number of bleed points. In other words, at pressures above the azeotropic point the binary vapour quantity bled condenses at a continuously decreasing temperature, and perfect approach to the Carnot efficiency can be realized with a finite number of extraction stages. Thus, for example, at a bleed pressure p_2 (assuming an infinitely large heat exchanger) the fluid can be heated from a temperature T_{b_0} to T_{d_0} (Fig. 4) with absolute reversibility, while in the case of preheating by condensing steam perfect reversibility cannot be attained, even with an infinitely large heat exchanger.

Naturally, maintenance of a constant temperature differential in the heat exchanger is also a function of the change in specific heat of the medium in the course of its evaporation and superheating. Similarly, the process of regenerative preheating of the liquid is also affected by changes of state arising during expansion.

In the course of research conducted up to now, no medium suitable for carrying out this suggestion has yet been found, as all existing media possess an evaporation zone in which the temperature difference between boiling point and dew point for the same mixture ratio is great only at a low temperature level.

Another possibility, nearer to present practice, is to ensure a minimum temperature differential in the process of heat transfer to the working medium by supplying heat at supercritical pressure. Here again, water vapour cannot be used, because its critical temperature is well above the value of about 300°C permissible in the reactor; a medium has therefore to be employed with a critical point which is lower (or at least not much higher) than the lower temperature (after the heat exchanger or before entry into the reactor) of the reactor coolant. In this case expansion will take place entirely in the superheated region, ensuring good thermodynamic efficiency. As a matter of fact, if expansion were permitted to take place in the normal way, this would involve serious disadvantages. Thus, the steam is in a very superheated condition at its final point of expansion, and a substantial part of heat transfer, at the condenser pressure determined by the lower temperature limit, would take place, not isothermally but at decreasing temperature, causing a substantial loss, compared with the theoretical maximum work attainable. Moreover, the liquid at supercritical pressure could not be regeneratively preheated to the required temperature before its entry into the primary heat exchanger, thus greatly reducing the reversibility of

heat transfer in the primary heat exchanger and impairing the efficiency of the system.

These disadvantages can be eliminated by using the power cycle shown in Fig. 5. The reactor coolant enters the primary heat exchanger at a temperature T_{r_1}, where it is cooled down to a temperature T_{r_2}, while it heats the working medium to a temperature T_3, reaching a temperature T_2 at supercritical pressure. The working medium enters the high-pressure stage of the turbine at a temperature T_3, where it expands to a temperature T_4 (disregarding losses). Expansion is here interrupted, and steam is extracted from the turbine and introduced into a second heat exchanger, where it is cooled at constant pressure to saturated condition (temperature T_5), while the liquid at supercritical pressure and in counter-flow is heated from temperature T_1 to temperature T_2. The saturated steam, at a temperature T_5, is then recycled into the low-pressure stage of the turbine, where it is expanded to the saturation pressure corresponding to the lower temperature limit T_0. At the same time, with steam bled from the low-pressure stage of the turbine, the condensate at supercritical pressure is preheated to temperature T_1 in the regenerative feed-heating system.

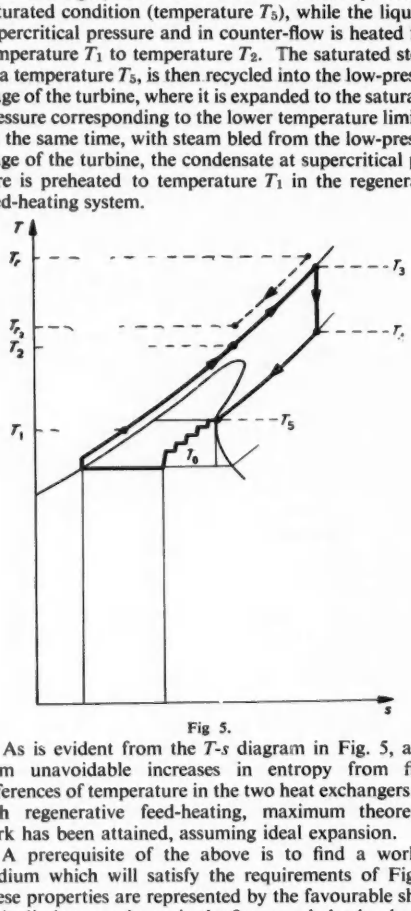

Fig 5.

As is evident from the *T-s* diagram in Fig. 5, apart from unavoidable increases in entropy from finite differences of temperature in the two heat exchangers and with regenerative feed-heating, maximum theoretical work has been attained, assuming ideal expansion.

A prerequisite of the above is to find a working medium which will satisfy the requirements of Fig. 5. These properties are represented by the favourable shape of the limit curve shown in the figure and also by the fact that the specific heats of the liquid at supercritical pressure and of superheated steam at the pressure corresponding to saturation temperature T_5 are identical between temperature limits of T_1 and T_2, and T_4 and T_5 respectively. Although further research is necessary to find a medium possessing such properties, it should be noted that, even now, materials exist which reasonably approach these ideal properties and whose application may result in substantial savings, compared with the saturated steam cycles so far advocated. Of such materials pentane (C_5H_{12}) appears to have satisfactory properties, and data

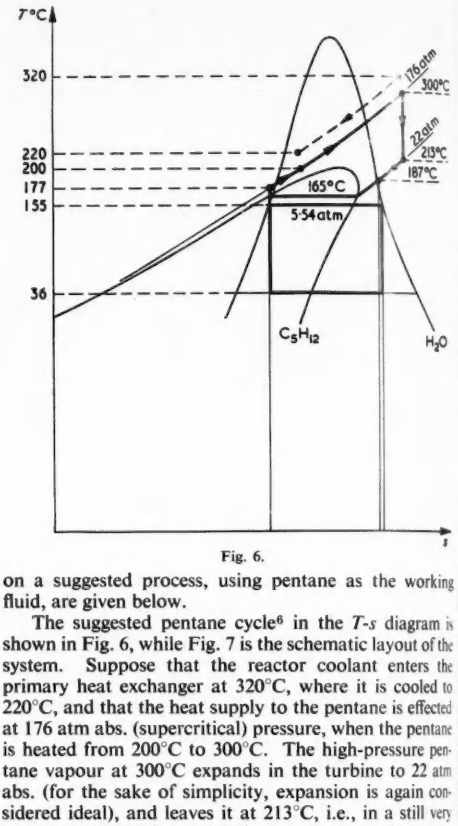

Fig. 6.

on a suggested process, using pentane as the working fluid, are given below.

The suggested pentane cycle[6] in the *T-s* diagram is shown in Fig. 6, while Fig. 7 is the schematic layout of the system. Suppose that the reactor coolant enters the primary heat exchanger at 320°C, where it is cooled to 220°C, and that the heat supply to the pentane is effected at 176 atm abs. (supercritical) pressure, when the pentane is heated from 200°C to 300°C. The high-pressure pentane vapour at 300°C expands in the turbine to 22 atm abs. (for the sake of simplicity, expansion is again considered ideal), and leaves it at 213°C, i.e., in a still very superheated condition, arriving at the second heat exchanger, where it is cooled at constant pressure to 187°C, heating to 200°C the pentane condensate formed in the water evaporator up to the temperature of entry into the primary heat exchanger. The pentane vapour at 22 atm abs. and 187°C condenses in the evaporator, while it evaporates water at 5·54 atm abs. ; the steam produced is made to expand in a suitable turbine to the condenser pressure corresponding to a condensing temperature of 36°C. At the same time, this secondary saturated steam cycle is made to approach ideal Carnot efficiency by regenerative feed-heating. The introduction of the steam cycle is necessary, because the limit curves of pentane differ from those of the ideal medium according to Fig. 5, and the expansion in the low-pressure stage would still take place in the superheated region, which would, on the one hand, further increase entropy during condensation, and, on the other hand, would prevent approach to the ideal Carnot cycle by regenerative feed-heating. Naturally, the temperature differential of 10°C in the evaporator also involves an increase in entropy; however, according to the author's calculations, the irreversibility of this solution is in this case smaller than it would be if pentane were made to expand down to a condenser pressure corresponding to a temperature of 36°C.

With the above numerical values, and taking into account the work expended by the pentane pump, the thermal efficiency of the complete system can be calculated as 39·03%.

In the following, the efficiency of the pentane-steam system, according to the cycle in Figs. 6 and 7, is compared with the saturated steam cycle suggested by d'Epinay and Lüthi[1], and by Beldecos and Smith[2]. In the comparative calculations the surface of the primary heat exchanger is assumed in both cases to be infinitely large. Calculation on the basis of an infinitely large surface yields good possibilities for practical comparisons. Expansion in both cases is considered ideal, and a perfect approach to the Carnot cycle is assumed for both the saturated steam cycle and for the steam section of the pentane-steam cycle. However, the two additional heat-exchanger surfaces in the pentane system have been estimated with a temperature difference of 10°C, because calculations based on an infinitely large surface would have been a disadvantage in the case of the saturated steam cycle, where no such surfaces are required.

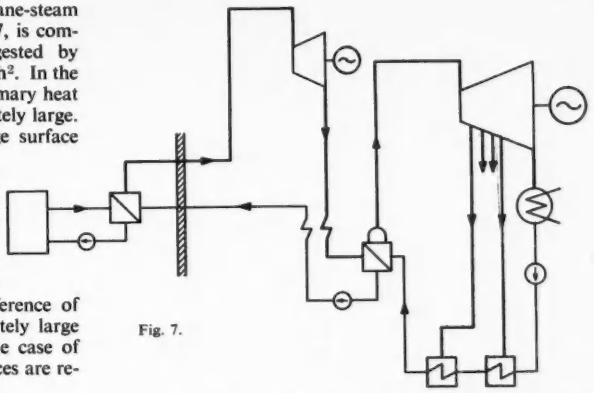

Fig. 7.

In the case of an infinitely large primary heat-exchange surface, the pentane is heated from 217 to 320°C, while the reactor coolant is cooled from 320 to 217°C. In this case the expansion of pentane vapour takes place from 176 to 20 atm abs., the final expansion temperature being 232°C. In the heat exchanger the superheated pentane vapour is cooled from 232 to 175°C, heating the liquid pentane at 176 atm abs. from 165 to 217°C. Simultaneously, the slightly superheated pentane vapour reaching the evaporator at 175°C condenses at 162°C (the saturation temperature corresponding to 20 atm abs.), while it evaporates water at 5·12 atm abs. at 152°C.

According to the above, the thermal efficiency of the whole pentane system will be 42·11%, while the efficiency of the saturated steam process, assuming an infinitely large primary heat exchanger, is 36·9% at the resulting upper limit temperature of 217°C. The proposed pentane system thus yields a thermal efficiency which is higher by (42·11—36·9)/36·9 = 14·11% than the ideal saturated steam cycle applicable under the same conditions.

In practice, the difference in efficiency between the two systems will be still more to the advantage of the pentane system, because the figures given for the temperature differential do not represent optimum values, and the advantage of a perfect approach to the Carnot cycle applies for the whole system in the saturated steam process, whereas it affects only the steam side of the pentane-steam process. Finally, a further by no means negligible advantage of the pentane system is the fact that, should it be considered economical to reduce the power required for circulating the reactor coolant, with a consequent increase in the temperature difference ($T_{r_1} - T_{r_2}$), the resulting reduction in efficiency will be less in the pentane system than it will be in the saturated steam system. The reason for this is due to the fact that the upper temperature in the pentane system will be reduced only in proportion to the reduction in the average temperature of heat introduction, whereas in the steam cycle it will be lowered by the full value of the reduction in the lower temperature of the reactor coolant, since, in the case of an infinitely large surface, the upper temperature of the steam process is always identical with the lower temperature of the reactor coolant.

It should be understood that, in the above examples, pentane has been chosen merely for the purposes of calculation, no consideration having been given with regard to any of its properties which may give rise to technical difficulties in practice, or which may be disadvantageous from a thermal point of view (e.g., viscosity, coefficient of heat transfer, etc.). It is, of course, quite certain that materials with more favourable thermal and physical properties than pentane will eventually be found.

A definite possibility exists for an even greater improvement in efficiency of nuclear power plants by combining nuclear energy with energy derived from conventional fuels. Literature on this subject would appear to reflect the belief that nuclear power stations should be entirely nuclear. This view is considered erroneous, except in the case of countries possessing hydro-electric power exclusively (and then only for the time being). There can, of course, be no doubt that for a very long period electrical power will continue to be generated from conventional fuels. Consequently, quite apart from the construction of nuclear power plants, every effort should be made to boost the efficiency of power generation from conventional fuels. This can be achieved by the development of atomic power stations on the basis of combined nuclear and conventional power generation. The importance of this solution is enhanced by the fact that, in the initial stage of construction of nuclear power stations, the cost per unit produced will obviously be higher than that of the most efficient modern thermal power stations, and the combination would, by virtue of reduction in costs, help nuclear power stations over the difficulties of this period of adjustment.

Margen[3] has suggested a combination in which nuclear energy released is used for feed-heating of a thermal power plant, thus making use of the very low reactor temperature. However, this solution would have the disadvantage of limiting very considerably the possibilities of extension of the nuclear power section of the plant, thereby restricting it to an unimportant fraction of the whole power station.

Possible methods of combination which eliminate this disadvantage exist. The low temperature level available in nuclear power stations makes it possible to use the heat derived from conventional fuels exclusively for additional heating of the working medium, permitting the maximum possible efficiency to be attained by the utilization of such heat. This becomes apparent if the processes taking place are analysed in the *T-s* chart (Fig. 8) for a power station operated on the cycle shown in Fig. 9. In the system investigated, the pentane cycle according to Figs. 5 and 6 is combined with the use of conventional fuels. The pentane, at a supercritical pressure p_0 and heated to a temperature T_3 in the primary heat exchanger, is superheated to the maximum temperature T_5 permitted by the creep strength of the material used. This heat input is carried

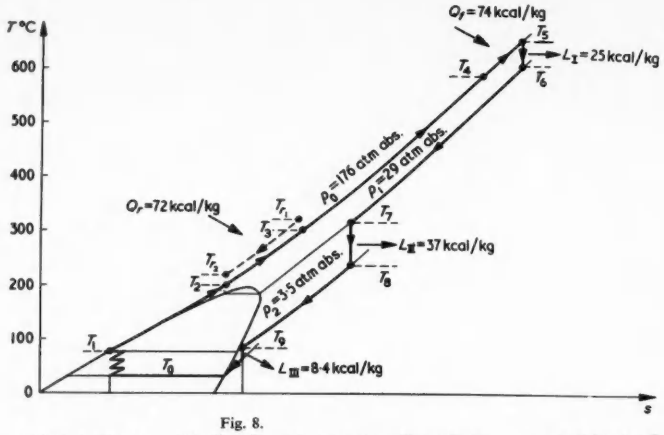

Fig. 8.

out in two stages. Heating from temperature T_3 to T_4 is effected by interrupting the expansion of pentane vapour (introduced into the turbine at temperature T_5) at a pressure p_1, extracting the vapour from the turbine, and conducting it through a second heat exchanger, where it cools down from temperature T_6 to T_7, heating the working fluid at a pressure p_0 from T_3 to T_4. The vapour, at a temperature T_7, is then recycled into the turbine, where it expands to a pressure p_2. Here, expansion is again interrupted, and the vapour extracted from the turbine is at pressure p_2, cooled from a temperature T_8 to T_9 in the third heat exchanger, where the working fluid at pressure p_0 is heated from temperature T_1 to T_2. The vapour is then recycled into the turbine, where it expands to condenser pressure. By feed-heating with bled steam from the low-pressure turbine, the temperature of the condensate is raised from T_0 to T_1. Bearing in mind the low value resulting from pressure p_2, it does not pay in this case to introduce a steam cycle, as in Fig. 7.

As can be seen from the T-s diagram, in the suggested cycle the external heat supplied by conventional fuels is introduced into the system between temperature limits T_4 and T_5, and thus the average temperature of external heat supply is higher than that so far attainable in the best steam systems known to date.

With the numerical values given in Fig. 8, the efficiency can be estimated as

$$\eta = \frac{L_I + L_{II} + L_{III} - L}{Q_f} = 57{\cdot}2\%$$

where L = the work gained in the case of a pure nuclear plant = 28·1 kcal/kg. This value is much higher than any ever attained in a thermal power station.

The combination suggested is, of course, also feasible if steam is generated in the primary heat exchanger with reactor heat, when it is estimated that the efficiency will be of the order of 57·5%. Another possibility of improvement lies in supplying the heat from conventional fuels at two or more stages, so that isothermal heat introduction is approached.

In applying the systems just discussed, there arises the interesting prospect of introducing external heat from conventional fuels, in which this heat supply is combined with an open-cycle gas-turbine process. In this case the conventional fuel is not burnt in a furnace specially developed for the purpose, but is fed into the combustion chamber of an open-cycle gas turbine. The heating surface for heating the working fluid is located between the combustion chamber and the gas turbine, the system being laid out in such a way that combustion gases enter the turbine at the highest permissible temperature after giving up the required amount of heat. In this case the efficiency of heat generation referred to the heat introduced into the working medium is practically 100%, taking into account the resulting changes in the gas-turbine cycle. There are two factors conducive to improving efficiency in the suggested cycle. Of these, one is that the work expended in compression, for the same gas-turbine performance, is reduced, because the turbine receives a greater quantity of combustion gases corresponding to the excess of fuel burnt, and at an unchanged temperature. The second factor is that, with the same regenerator surface, the flue-gas losses increase negligibly, and not in proportion to the surplus fuel, since the original amount of air supplied to the system also covers the

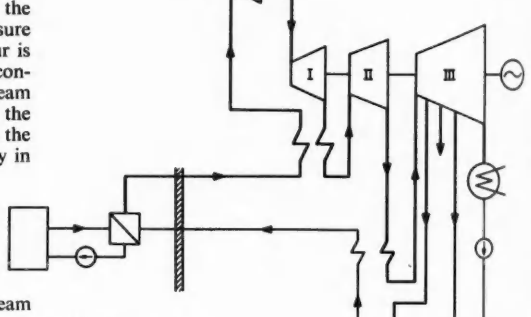

Fig. 9.

combustion-air demand of the surplus fuel. Although every case must naturally be considered individually, detailed estimates by the author to determine the rate of heat consumption of the gas turbine have resulted in values so low that they cannot be approached in the foreseeable future in any other way.

The above method may also prove of interest if

(*Concluded on page 297*)

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Problems of Electro-Hydraulic Controls for Machine Tools

By A. DÜRR. (From *Konstruktion*, Vol. 8, No. 5, May 1956, pp. 192-203, 35 illustrations.)

In the design of electro-hydraulic systems, suitability and cost are major considerations; however, in the author's view, the decisive problem of electro-hydraulics is that of utilizing to the fullest extent all the specific properties of the two different media. In this paper, the basic principles of recently developed electro-hydraulic units are described, together with indications of how various problems of importance in practical applications can be overcome.

In machine tools the main operations for the tool or the work involve chucking and clamping motions, approach and return motions, and transport motions, it being particularly important that the feed should be effected with the least possible vibration.

Linear motion can be produced hydraulically in a simple manner by means of a cylinder and a piston actuated by pressure oil supplied from an external source. Many suggestions and patents have been published with the object of improving the uniformity of motion of the hydraulic piston ; however, it has been found in practice that the freely moving piston does not always fulfil requirements, particularly when operating with hard-metal tools and when large strokes are involved.

The hydro-mechanical drive provides considerably more favourable operating conditions. In place of the cylinder, this arrangement employs a hydraulic motor which drives a robust screw spindle, either directly or through a reduction gear. With this system, the adverse effects arising from the compressibility of the pressure oil are extensively eliminated. Vibration is reduced, and improved uniformity of motion is thus obtained. The disadvantages of the hydro-mechanical drive, however, are its lower mechanical efficiency, requiring a greater delivery from the pump, and its somewhat higher cost. Nevertheless, in recent years the hydro-mechanical drive has been increasingly adopted and has replaced the simple cylinder and piston in many processes requiring rectilinear motion. It is now also employed for rotary, circular, pendulum, and pivoting motions. Two further important advantages of the hydro-mechanical drive are that it enables a machine component to remain locked when the hydraulic system is cut off, and that it permits accurate adjustment by means of a handwheel and dial.

In electro-hydraulic control units, the hydraulic component consists basically of a pump control which regulates the delivery of the pump, and a valve control which determines the direction of flow of the pressure fluid.

Problems of Pump Controls

Single units for the control of pump delivery in one direction only are very commonly used, particularly in multiple cycles, these units being connected to the pump either simultaneously or in succession. Separate control units are, however, necessary for reciprocating motions. It is also possible to control pump delivery in both directions, i.e., with reversal of motion while passing through the zero position, and in this case the additional control unit becomes unnecessary. In general, however, with this type of unit only one circuit or cycle is controlled. An accurate mid-point or zero position is somewhat difficult to obtain with this arrangement ; moreover, for accurate operation it is essential to provide for manual adjustment of the hydraulic motor in the stop-position, and, as pressure oil is displaced in this adjustment, an additional control unit is necessary. Similarly, unfavourable conditions occur when the volume of the cylinder ahead of and behind the actuating piston is large, the discharge or intake of differential quantities on either side of the feed unit again requiring an additional control valve. Consequently, the use of a single unit operating in both directions is practicable only in feed-control applications, and even then is an advantage only in certain cases.

For control systems with pump delivery in one direction only, three different possibilities may be considered, as follows :—

(a) " Start " and " stop " cycles, with an arbitrarily selected position for the delivery, which can be infinitely adjusted between zero and maximum.

(b) " Rapid-approach ", " feed ", and " stop " cycles, where rapid approach and stop correspond to the fixed maximum and zero end-positions of the feed unit, whereas the feed position can be any value between these two.

(c) " Rapid-approach ", " feed ", and " slow or fine-feed " cycles, in which case there is no stop position for the pump, i.e., no zero-delivery condition. The slow position serves for accurate adjustments and also for small motions during setting-up of the machine.

Arbitrary adjustment of delivery can be effected by purely mechanical means, e.g., with a screw spindle and handwheel, or control knob acting on a curved contour.

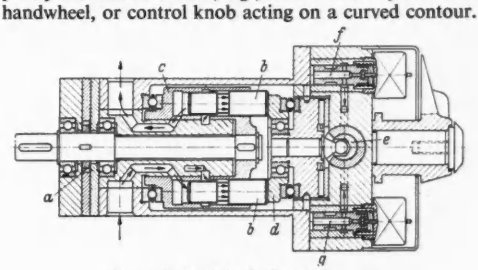

Fig. 1. **Self-priming feed-control pump.**

Conditions become more difficult with hydraulic or electro-hydraulic adjustment of the pump to the required delivery. A self-priming feed-control pump is shown in Fig. 1, and comprises a small gear pump *a* used as a control pump, and a piston-type pump with nine differential plungers *b* in a rotating drum *c*. The pistons are subjected to the pressure of the oil from the gear pump on their differential surfaces and bear on a rotating swashplate *d*. The swashplate is very rigidly supported in two needle bearings mounted in two hardened bearing segments. On both sides of the positioning piston *e* there are small solenoid valves *f* and *g* which regulate the system for rapid approach, feed, stop, or fine-feed.

This feed-control unit has a number of special design features. Fig. 2A is a schematic drawing of the positioning head, shown in the fine-feed position. Two positioning pistons are required, i.e., an internal spring-loaded piston *a* and an external piston *b* with a guide-pin *c* and a roller *d*. Piston *a* is pressed downwards by a spring against an adjustable stop *e*, which is set so that the pivoted swashplate cannot move back completely to the zero position. The pump thus still delivers a small adjustable quantity.

In the next position of the head, in this case for " feed " (Fig. 2B), pressure oil is supplied from the small

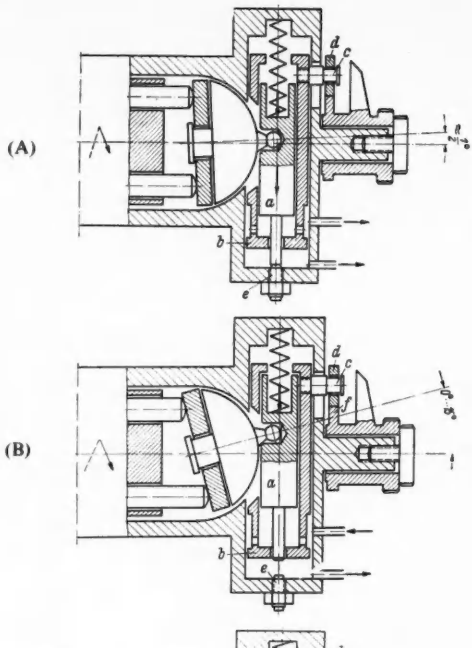

Fig. 2. **Schematic drawing of positioning head, shown (A) in the "fine-feed" position, (B) in the "feed" position, and (C) in the "rapid-approach" position.**

gear pump (control pump in Fig. 1) to the internal positioning piston *a* by actuation of a solenoid valve. This piston moves upwards inside piston *b* towards the stop *e*. The spring also acts on piston *b* and maintains it via the roller *c* on the contour *f*. When the control knob is turned, the piston *b* follows the contour, owing to the spring load. As this contour is designed as a logarithmic curve, delivery can be adjusted very accurately.

For "rapid approach", i.e., the maximum delivery position of the pump, oil is supplied through both pressure lines, as shown in Fig. 2c, both solenoid valves being energized. Oil pressure is now also exerted on piston *b*, and both positioning pistons move against the spring load to the upper end of the stroke. The swashplate reaches its maximum angle of about 25 deg.

A problem with this control arrangement is the accuracy of delivery over the entire feed range with varying working pressures and temperatures. Assuming that, under rapid-approach conditions, the pump delivers 100 litres/min, which would correspond to a rate of advance of 4 metres/min, and that the feed should be adjustable between 20 and 1000 mm/min, then for the minimum feed or "fine-feed" condition, the required delivery is 500 cm³/min, so that the entire positioning range corresponds to a ratio of 1 : 200. Such wide ranges can be maintained with the required degree of reliability only by extremely careful design and manufacture and by the selection of appropriate materials. In particular, losses through internal and external leakage should be maintained at low values ; in addition, it is necessary to consider the delivery losses during pressure rise caused by elastic deformation of the drive members, and the compressibility in the dead spaces of the cylinder. As an example, it may be mentioned that, over a range of working pressures from 0 to 35 atm gauge, there is a nearly linear increase in losses, i.e., up to 18% for external leakage losses, up to 12% for internal leakage losses, up to 10% for compression losses, and up to 5% for losses due to elastic deformation.

To improve conditions at the lower end of the range, various other features have been developed. The delivery loss of the pump during the pressure rise can be compensated by means of the arrangement indicated in Fig. 3, in which the positioning piston is now modified to include a further piston *g*, in which the pivoting portion of the swashplate is inserted. The lower surface of piston *g* is in contact with pressure oil from the pressure line of the pump. When a pressure rise occurs, piston *g* moves upwards against the load of a spring *h*. During this motion, the pump reaches an increased delivery position. The amount of increase can be predetermined by choice of a corresponding spring characteristic. With this compensation, a practically flat delivery characteristic is obtainable for pressures up to 40 atm gauge. This characteristic, however, is not constant, but depends on the viscosity of the pressure oil and the condition of the pump. Excessive compensation is very dangerous for the tool, since a marked increase in feed rate, occurring simultaneously with an increase in pressure (i.e., in load), can very easily lead to fracture. In any case, it can be stated that the conditions over an operating period of a number of years are not sufficiently well defined and constant to permit effective and accurate compensation to be maintained with certainty.

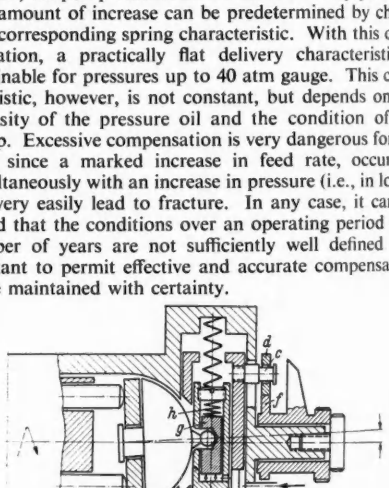

Fig. 3. **Positioning head modified for compensation of delivery losses.**

A further possibility for obtaining improved uniformity is to reduce the positioning range from, say, 1 : 200 to 1 : 100, by using an adjustable hydraulic motor. These motors have a capacity which can be varied automatically in a ratio of about 1 : 2 when the pump is regulated for rapid approach. To achieve this, the pressure oil acts on a small axially movable positioning piston, the oil being supplied from the small solenoid valve for high-speed motion provided on the feed unit. At the same

time as the pump is positioned for maximum delivery, the capacity of the hydraulic motor is halved. This method of course, also reduces the transmitted drive torque to one-half of its previous value. Generally, however, this smaller torque is sufficient for the high-speed motion of a machine-tool table or slide.

Finally, the hydraulic motor can also be provided with an automatic speed-change arrangement, as indicated in Fig. 4. This arrangement comprises an annular piston *a*, which controls the engagement of the plates of multi-disc couplings *b* and *c* for transmission ratios of 1:1 and 1:4 respectively, a planetary gear unit *d*, a hollow drive shaft *e*, and an output shaft *f*. The axially movable stroke-positioning pistons *h* act on the swashplate *g*, which is in contact with the pistons in the drum *i*. The reduction gear can have any ratio between 1:2 and 1:4. In this way, it is possible either to reduce the positioning range of the feed unit or to increase considerably the entire range of speeds between minimum feed and rapid approach. The cost is, however, correspondingly greater.

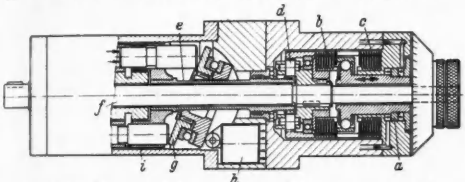

Fig. 4. **Hydraulic motor with automatic speed-change arrangement.**

The units described above permit manual adjustment by means of a control knob. In many machine tools, however, the pump controls are out of reach of the operator, who should then be provided with a suitable pendent control for remote operation of speeds and feeds. The continuously (stepless), or nearly continuously, variable electro-hydraulic positioning system for remote control consists basically of two precision-type potentiometers, rotatable through 180 deg. One of these is located on the control panel, while the other is located at the operating station, i.e., at the control spindle of the pump. The two potentiometers and a suitable relay are connected in such a way that, when the angular positions of both potentiometers coincide, the relay is neutral. If the position of one of the potentiometers is altered, the relay operates in one direction or the other and energizes a solenoid valve which allows pressure oil to flow to the positioning piston of the pump feed-control unit. Oil also proceeds from the positioning valve to a hydraulic device which readjusts the position of the potentiometer at the operating station. The relay and the solenoid valve return to the neutral position when both potentiometers are at the same setting. This feedback type of control is accurate to about $\frac{1}{4}$ deg., i.e., it is fully adequate for practical requirements. Obviously, it is also possible to regulate the pump speed over its entire range by remote control in a similar manner. This simple and useful arrangement gives fully reliable operation, as the initial problems of its application to machine tools have been satisfactorily solved. It enables stepless control processes to be incorporated into automatic programmes, and this feature is of considerable importance.

For special jobs on irregular shapes and on contours of large and intricate workpieces, a similar type of control can be used. Fig. 5 shows a manually adjustable arrangement with this type of remote control, the small, easily transportable control potentiometer being carried by the operator to any required location. This system comprises

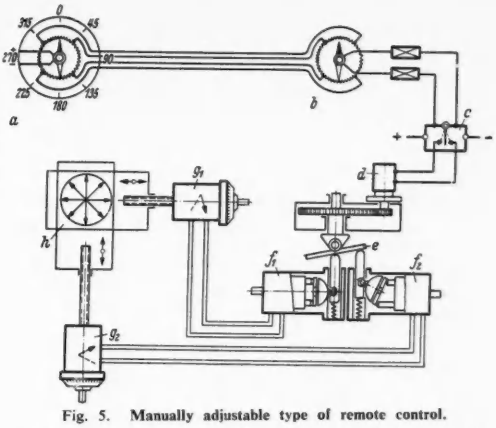

Fig. 5. **Manually adjustable type of remote control.**

two precision-type potentiometers *a* and *b*, rotatable through 360 deg., with 10-deg. tappings and provided with contact fingers at 180 deg. to each other. When the dial of the control potentiometer *a* is turned to any required position by the operator, the relay *c* is energized and operates the positioning motor *d*, which acts via a reduction gear on a swashplate *e*, varying the position of two feed pumps f_1 and f_2. Each of these pumps operates in a closed cycle in conjunction with a hydraulic motor, i.e., motor g_1 for longitudinal motion, and g_2 for transverse motion of the table *h*. The resulting motion corresponds fairly accurately with the dial setting at the control-panel station. As both feed pumps are regulated according to a sine law in their delivery through the zero position in either direction, the resulting velocity in any arbitrary direction is constant, i.e., it depends only on the angle of the swashplate. Positioning accuracy decreases at small angular settings of this swashplate, i.e., at low feed rates. The problem is again that of obtaining the required accuracy by minimizing backlash, elastic deformation, etc., over a wide range of adjustments.

Hydraulic Feed Systems with Self-Regulating Pumps

Control to fixed but predetermined outputs for rapid approach, feed, and fine feed can be effected with adjustable pumps of the types considered ; however, increasing use is now being made of pumps in which automatic setting of output is obtained directly from the system pressure. In this pump the adjusting elements are preloaded by a helical spring or by hydraulic pressure, and, with increasing system pressure, output tends to be reduced to zero. As this pump delivers only as much oil as is required in the operating cycle, and no more, efficiency is very high, and no unduly high amount of heat is generated. A pump of this type is shown in Fig. 6, where the positioning piston *a* is subjected to a hydraulic load

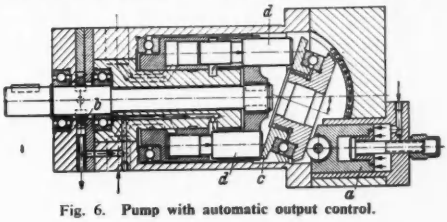

Fig. 6. **Pump with automatic output control.**

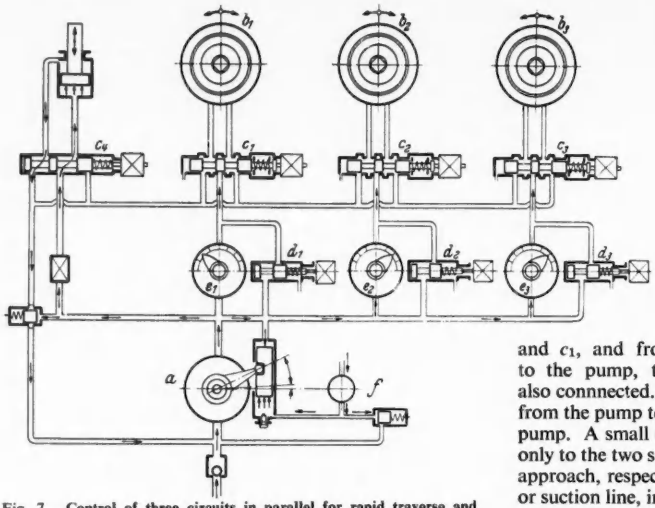

Fig. 7. **Control of three circuits in parallel for rapid traverse and reversing.**

from a small control pump *b*, which holds the plungers *d* against the swashplate *c* during the suction period. Should the system pressure rise unduly, the reactive forces of plungers *d* on the swashplate *c* will overcome the pressure exerted by piston *a*, tending to straighten the swashplate and consequently to reduce output. Similarly, a reduction in system pressure permits piston *a* to tilt the swashplate, giving a corresponding increase in output. The characteristic of this pump is remarkably well suited to operating requirements, giving, for instance, 100 litres/min from 0 to 28 atm gauge system pressure, with a practically linear decrease to zero output between 28 and 30 atm gauge. Similarly, on the return stroke, delivery increases from zero at 30 atm to 100 litres/min at 25 atm gauge, and is constant thereafter for the lower working pressures, so that the hysteresis of the cycle is comparatively small.

This type of pump is particularly useful in systems with multiple circuits. The pump *a* and its control pump *f* may be used, for instance, to control three circuits in parallel for rapid traverse and reversing, as shown in Fig. 7, in which b_1, b_2, and b_3 are hydraulic motors, c_1, c_2, c_3, and c_4 are reversing valves, d_1, d_2, and d_3 are rapid-traverse controls, and e_1, e_2, and e_3 are magnetic control units. The processes can be either simultaneous or successive and, with these pilot valves, the pressure in each circuit can be maintained within 5 atm gauge, e.g., between 25 and 30 atm. The hydraulic motors can be individually adjusted to different preselected speeds. A disadvantage in connection with these pumps in this system is that the single pump unit is required to operate constantly at a high maximum pressure, which may be needed only occasionally for heavy-duty conditions. In systems with adjustable pumps, the system pressure is in most cases well below the maximum pressure, so that the pumps are subjected to much lower loads.

Problems of Valve Controls

As previously stated, the electro-hydraulic control system comprises feed units, hydraulic motors, and control valves. Fig. 8 shows a typical system with three hydraulic motors b_1, b_2, and b_3 for longitudinal, transverse, and vertical motions. The solenoid valves c_1, c_2, and c_3 are shown in the middle position, where they shut off the supply of pressure oil from the pump *a* to the motors. In order that the motors may be rotated manually for any necessary adjustments, both connecting lines are short-circuited in this position. As the pump has no zero position in this arrangement but is designed with an adjustment for fine feed, the three pilot valves have an additional control element for returning the small feed quantity to the suction line.

The return line is connected in series with control valve c_3 via c_2 and c_1, and from the latter to the common return to the pump, to which all the valve discharges are also connnected. The system is a closed hydraulic circuit from the pump to the actuating positions and back to the pump. A small control pump *d* delivers pressure oil not only to the two solenoid valves *e* and *f* (for feed and rapid approach, respectively) but also into the common return or suction line, in order to compensate any losses of pressure oil in the cycle. The small back-pressure of a few atmospheres, produced by the control pump, is sufficient to maintain the plungers against the swashplate during the suction or filling period. Thus, in this system it is necessary to have small differential plungers, as shown in the self-priming pump unit in Fig. 1.

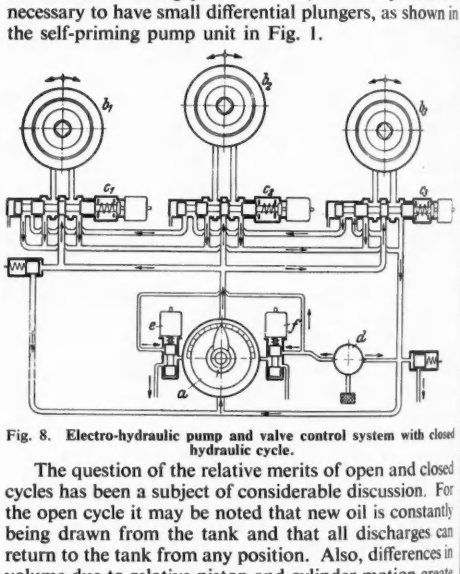

Fig. 8. **Electro-hydraulic pump and valve control system with closed hydraulic cycle.**

The question of the relative merits of open and closed cycles has been a subject of considerable discussion. For the open cycle it may be noted that new oil is constantly being drawn from the tank and that all discharges can return to the tank from any position. Also, differences in volume due to relative piston and cylinder motion create no difficulties, i.e., it is immaterial whether the quantity discharged from the cylinder is large or small, ahead of or behind a piston. On the other hand, a self-priming pump is required, and this is usually expensive.

For the closed cycle, the primary feature is that, owing to the back-pressure in the suction line, very small quantities can be delivered accurately and reliably, and that during maximum delivery (high-speed motion) there are no suction losses due to incomplete filling, even with cold pressure oil. In a pump distributor, the pipe cross-sections are kept as small as possible to obtain accuracy in

(*Continued on page 296*)

Power Augmentation with Nitromethane

By E. E. STARKMAN and E. S. MOULIC. (From *Automotive Industries*, Vol. 114, No. 8, April 15, 1956, pp. 56–59, 158, 162, 164, 168, 14 illustrations.)

Although nitromethane has been used for the last ten years to increase the output of racing engines, particularly on dirt tracks, little if any information is available on specific performance figures or on the mechanism by which this material functions. The purpose of this paper is to report on the results of the initial phases of a systematic investigation into the application of nitromethane in engines.

NITROMETHANE is a clear colourless liquid of molecular weight 61. It has a specific gravity of 1·14 at 20°C and a gross heating value of 5000 BTU/lb. It is only slightly soluble in aliphatic hydrocarbons, more soluble in aromatics, and very soluble in the lighter alcohols. If subjected to shock, it has a tendency to decompose with considerable violence, and to explode in the manner of certain other organic nitrogen compounds, e.g., TNT. The degree of shock is apparently quite high, since it may be shipped labelled only as a combustible, and not as an explosive material.

It is toxic only to the extent of such materials as petroleum naphtha or methyl isobutyl ketone, or in concentrations greater than 100 ppm in air. Thus, nitromethane is relatively safe to handle, using reasonable precautions, especially when diluted in alcohol or hydrocarbon fuel.

The amount of oxygen (52½% by weight) contained in the nitromethane molecule is not so important as is its bonding before and after the combustion reaction. As an example, the oxygen in water has little energy value in admixture to a fuel, because it is already in the lowest energy form to which it can be reasonably subjected by combustion. In the case of nitromethane, the fuel-contained oxygen is available. The degree to which such bonding energy can be used is a function of the composition of the products of combustion.

If the fuel is allowed to decompose by itself, with no oxygen from the atmosphere or elsewhere, such decomposition is believed to proceed as follows :

$$4CH_3NO_2 \rightarrow CO_2 + 3CO + 3H_2O + 2N_2 + 3H_2$$

This would be the reaction when used as a monopropellant in a rocket, or if used in a piston engine without air. However, as at present used in piston engines, and if burned at a chemically correct mixture ratio with air, the reaction is likely to be :

$$4CH_3NO_2 + 3O_2 + 11{\cdot}3N_2 \rightarrow 4CO_2 + 6H_2O + 13{\cdot}3N_2$$

The chemically correct fuel/air ratio by weight for this reaction is 0·588. It can be recognized that this is quite a rich mixture ratio when compared with hydrocarbons, say, iso-octane (C_8H_{18}), which has a chemically correct fuel/air ratio of 0·0662. Even methyl alcohol, which must be burned very rich compared with hydrocarbon fuels, has a chemically correct fuel/air ratio of only 0·154. Thus, the use of nitromethane, even as an additive in moderate concentration, necessitates a drastic change in fuel metering.

The potentials for use of undiluted nitromethane for non-air-breathing piston engines are obvious. Unfortunately, any attempt at this time to establish this point would be too hazardous, especially since the danger involved has already been exemplified by the many rocket-engine experiments which have come to an abrupt end.

In a reciprocating engine the same tendency of nitromethane to become unstable with relatively little provocation at high temperatures and pressures leads to preignition. It is therefore at present limited to being used as an additive to other fuels. The concentration to be tolerated is indicated by the pre-ignition or knocking tendency, and this, in turn, is primarily a function of the engine operating conditions, combustion-chamber configuration, and the composition of the fuel of which it is a constituent. It should be apparent that the fuel to which it is being added must, before dilution with nitromethane, be of relatively high anti-knock quality. It should also be apparent that keeping the engine cool is of primary importance.

An additional restriction, caused by relative insolubility, makes it necessary to use unorthodox hydrocarbon blends, or alternatively alcohol blends. Thus, for this investigation, methyl alcohol was used as one base fuel, and an equal volume of benzene and iso-octane as another, with the concentration of nitromethane limited to that which would cause violent pre-ignition.

EQUIPMENT

For the initial work a two-cylinder, Lawrence Model 30D engine with horizontally-opposed, air-cooled cylinders and of 2⅝ in. bore and 2¾ in. stroke was available. This engine was rated at 10 hp at 4150 rpm. An eddy-current dynamometer was used to absorb the output. As mixture distribution and acoustical problems were encountered in the carburettor and inlet manifold, research in this engine had to be abandoned in favour of a C.F.R. engine, even though it was felt that the high speed of the Lawrence engine might be important to the investigation, because it was suspected that high flame speed was one beneficial effect of the nitromethane.

A standard single-cylinder supercharged C.F.R. installation was used as the second laboratory engine. The compression ratio was set at 6 to 1. In all cases the manifold pressure was adjusted to 30·0 in. of mercury absolute, and the manifold air temperature to 125 ± 5°F. Other than the above, the engine was operated in the normal fashion.

RESULTS WITH LAWRENCE ENGINE

The effect of nitromethane was first determined by measuring full-throttle brake horsepower as a function of air/fuel ratio at constant speed and spark advance in the Lawrence engine. Methanol was used as the base fuel, and concentrations of 5, 10, and 15% nitromethane by volume were tested.

Because of difficulties with pre-ignition of the 15% nitromethane concentration, which led ultimately to a piston failure, only data for the two lower-content blends are shown in Fig. 1. These data are for 3500 rpm and they proved conclusively that nitromethane definitely had beneficial effects on power output, even in this air-cooled engine. It should be remembered that the Lawrence engine drives its own blower for cylinder cooling as well as many other auxiliaries. Thus, the increased output reflects a low mechanical efficiency of the engine.

These early but conclusive results qualified further study. However, the Lawrence engine was abandoned at this point because of the previously mentioned difficulties,

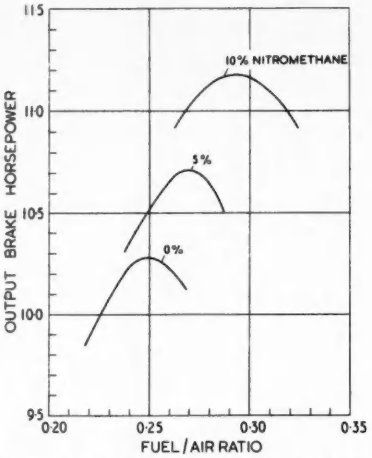

Fig. 1. **Performance with nitromethane in methanol in the Lawrence engine.**

and research was therefore transferred to the C.F.R. installation.

Results with C.F.R. Engine

Methyl Alcohol Base Fuel

Fig. 2 is a direct plot of the indicated mean effective pressure as a function of fuel/air ratio, resulting from various concentrations of nitromethane blended in methyl alcohol up to the pre-ignition-limited concentration of 20% by volume at a very high jacket temperature of 375°F. With the methyl alcohol base fuel alone, maximum obtainable indicated mean effective pressure was 142 psi. With 20% nitromethane, the maximum indicated mean effective pressure was 160 psi. It is also evident that the optimum-power fuel/air ratio was changed from about 0·20 to 0·30 lb fuel per lb air from the base fuel to the 20% nitromethane blend.

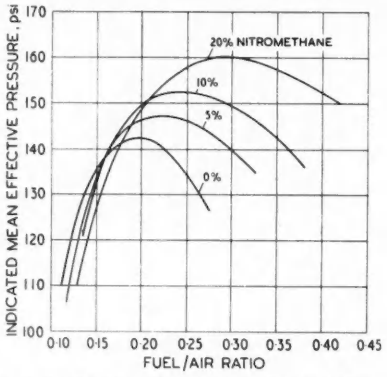

Fig. 2. **Results with nitromethane in methanol in the C.F.R. engine, with a jacket temperature of 375°F.**

As important a consideration as power output is the rate at which fuel will be consumed in any given situation. The data of Fig. 2 have therefore been replotted in Fig. 3. It can be seen that the minimum specific fuel consumption to be obtained is without any nitromethane in the fuel. With 20% nitromethane the minimum specific fuel consumption increased by 19%. This increase would be a

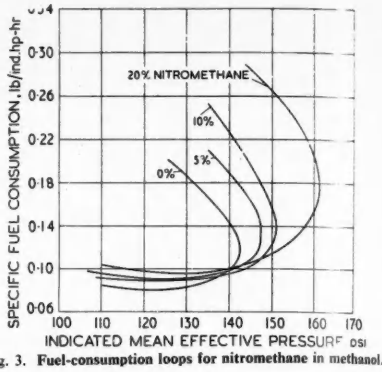

Fig. 3. **Fuel-consumption loops for nitromethane in methanol.**

considerable factor if the weight of fuel to be used is of any concern in a particular application.

Because of the shift to richer mixtures caused by the inclusion of nitromethane, it is profitable to view the results of Fig. 2 plotted as a function of percentage of optimum air/fuel ratio, as shown in Fig. 4, which gives a clearer picture of the influence of nitromethane and shows the increased latitude in mixture control, an additional advantage of the material.

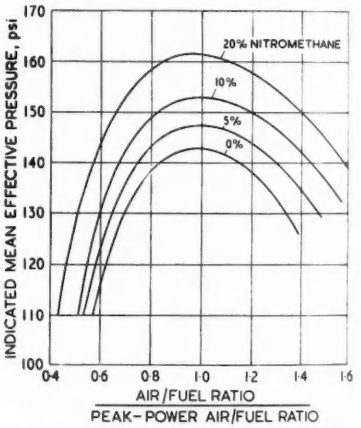

Fig. 4. **Influence of mixture control on output.**

The pre-ignition encountered at 20% concentration of nitromethane and 375°F jacket temperature was evidenced by a progressive loss of power which appeared at mixtures near chemically correct after a minute or two of operation at these fuel settings. Little audible knock was detected, but in certain cases power output fell to zero in as little as 15 sec, even though at very rich and at lean mixture ratios operation was perfectly satisfactory. The tendency to pre-ignition was so pronounced at 20% concentration that it was felt impractical to attempt to collect data at greater concentrations without lowering the jacket temperature. Therefore, the jacket temperature was lowered to 150°F and then it was possible to operate the engine on 40% by volume of nitromethane in methanol with some success. Unfortunately, this reduction in jacket temperature also changed the engine output for methanol alone, increasing this calibration or base value to 158 psi from 142 psi indicated mean effective pressure. The results obtained with a jacket temperature

of 150°F are shown in Fig. 5. The dashed portion of the curve for 40% is the region in which pre-ignition power losses still made data difficult to obtain.

By plotting the peak power values from Figs. 2 and 5 against nitromethane content it was found that, for the range of reliable data, the increased net output appears to be a linear function of nitromethane content and amounts to about 5% increase per 10% of the additive.

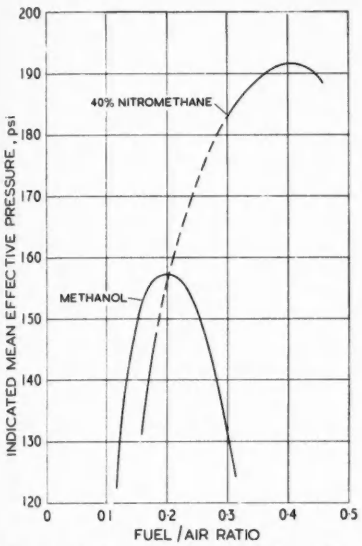

Fig. 5. **Results with nitromethane in methanol in the C.F.R. engine, with jacket temperature reduced to 150°F.**

So far the results presented are based on the gross output, efficiency, and specific fuel consumption. From a practical consideration friction must also be considered, especially for high-speed engines. This varies widely and is a function of the engine.

As an example, mechanical efficiency can be presumed to be about 75%. Since the addition of nitromethane would have little or no effect on friction horsepower in the engine, the percentage increase to be found in net or brake output would be far greater than the gross or indicated output as shown, for instance, in Figs. 2 or 5. Thus, the increased output at 40% volume concentration of nitromethane would be about 30%. This very large advantage would be increased even further by assuming a lower mechanical efficiency.

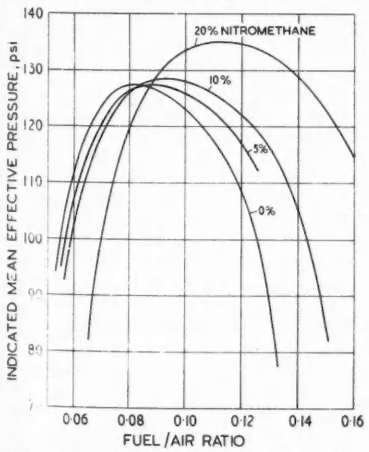

Fig. 6. **Influence on engine power of nitromethane in a hydrocarbon fuel, with a jacket temperature of 375°F.**

Benzene-Iso-octane Base Fuel

The results obtained from the addition of nitromethane in varying concentrations to a 50–50% by volume mixture of benzene and iso-octane are shown in Fig. 6. These data are for a 375°F jacket. Note that by comparison with Fig. 2, the mixture of benzene and iso-octane as a base fuel yields less output than methanol. The mixture of benzene and iso-octane was chosen because such a composition more closely approximates gasoline composition than methanol, but has a higher solubility for nitromethane than gasoline possesses. The maximum output was increased from an indicated mean effective pressure of 126 psi to 135 psi by using 20% by volume of the additive, which was the maximum which could be tolerated before pre-ignition began to have a large effect on power output.

Since pre-ignition was found to be the limiting factor in applying large concentrations of nitromethane, a cursory measurement was made of the knock tendencies of the various blends of nitromethane and iso-octane-benzene, and these were found to be quite serious.

Efficiency and Economy

As pointed out, the specific fuel consumption increased drastically with the addition of nitromethane. While specific fuel consumption is ordinarily considered sufficient for expressing relative thermal efficiency, because an inverse relationship is usually found to exist between efficiency and fuel consumption, this presumption is made on a constant heating value for the fuel used. When using nitromethane, with a heating value of only 5000 BTU/lb as one component of the fuel mixtures, it is necessary to go beyond an analysis of specific fuel consumption in order to ascertain the effect of varying nitromethane content on thermal efficiency. Thus, Fig. 7,

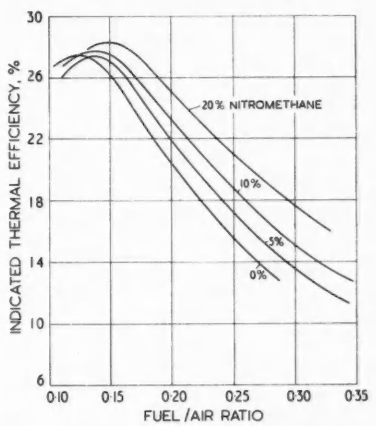

Fig. 7. **Effect on thermal efficiency of nitromethane in methanol.**

which shows indicated thermal efficiency as a function of fuel/air ratio, illustrates the fallacy which might result from presuming that indicated thermal efficiency and indicated specific fuel consumption might be inversely

related in the case of nitromethane. Fig. 7 shows that the indicated thermal efficiency actually increases from about 27% without any nitromethane to 28% with 20% by volume nitromethane, while from Fig. 3 it was noted that the specific fuel consumption increased by 11% or from 0·84 to 1·0 pounds of fuel per indicated horsepower-hour.

Influence of Compression Ratio and Spark Advance

Since the question of the effect of engine variables on results always arises, a brief review was made of two other items in addition to jacket temperature and fuel/air ratio. Results with methanol and methanol plus 20% nitromethane with different spark ignition timing showed that 45 deg. before top dead centre was a fortunate choice, since optimum power was obtained over a very wide range at this setting.

Increasing the compression ratio was expected to improve the engine output but aggravate the pre-ignition problem. No disproportionate effect of compression ratio on pre-ignition was experienced. This helps to explain why nitromethane has been used as successfully in engines with high-compression as well as in moderate-compression ratios.

Discussion of Results

At any power setting obtainable with the base fuel alone, the specific fuel consumption for the doped fuel was always higher. Therefore, the primary advantage to be realized from the addition of nitromethane lies in the greater available power output. A secondary but lesser effect is increased thermal efficiency, which actually contributes to the power available.

The comparison of percentage increase in power output from the use of nitromethane in the benzene-iso-octane mixture with that of the methanol fuel shows that it is more beneficial to include this same concentration in the methanol fuel than in the benzene-iso-octane mixture. These latter data would amount to a maximum net increase of about 7% for 20% nitromethane.

There is nothing mysterious about the greater increase in output from nitromethane in alcohol than from the same concentrations by volume in a hydrocarbon mixture. The total amount of nitromethane per unit time is greater in methanol fuel than it would be in hydrocarbon fuels, because more methanol is used per pound of air at the same output. Thus, the reason for the greater increase in power output available with the addition of nitromethane to methanol, as compared with the hydrocarbon fuel, lies primarily in the fact that equal volume concentrations of nitromethane in the methanol fuel represent a very much larger incremental increase in the amount of energy supplied by a unit charge of mixture.

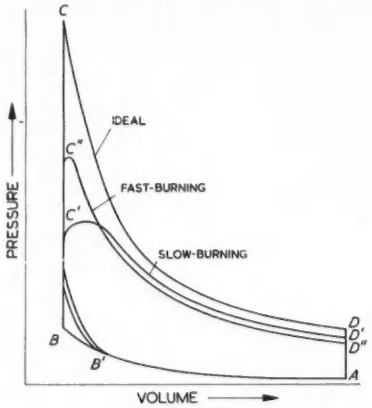

Fig. 8. Ideal and real cycles.

The most probable contributory factor to the increased thermal efficiency encountered, and perhaps for part of the increased power output, can be shown by Fig. 8, which illustrates the ideal or Otto cycle $ABCD$; also shown is a normally encountered real cycle diagram, $AB'C'D'$, as well as another cycle $AB'C''D''$, which would occur with an increased rate of pressure rise during the combustion process. This latter curve, it is felt, is representative of what must result with the addition of nitromethane, while the other is more likely to be found with a slow-burning fuel such as methanol. Because of its combustion characteristics and from the pro-knock evidence, it is felt that any fuel containing nitromethane must react more quickly than the base fuel, and thus cause the combustion process better to approximate the ideal constant-volume combustion, presumed as a basis for the ideal cycle. This latter, which might be called the flame-speed effect, could be pinned down by engine indicator records, but this has not been done as yet, primarily because of the complexities of application of equipment sufficiently reliable to differentiate the change in rates of pressure rise which might be involved.

Conclusions

(1) Nitromethane as a fuel additive in either alcohol or hydrocarbons is capable of increasing power output. At 40% nitromethane in methanol this represents an increase of 22% indicated or 30% brake output at 75% mechanical efficiency.

(2) The amount of nitromethane which could be added to a given fuel was limited by the tendency for the additive to bring about pre-ignition, with jacket temperature the largest controlling factor in determining the maximum concentration. In the case of its addition to methanol and for continuous operation, the concentration at 6 to 1 compression ratio, 125°F inlet, 375°F jacket temperature, and C.F.R. supercharge conditions amounted to 20% by volume. This 20% also was the limiting concentration when blended in an equal-volume benzene-iso-octane mixture. At 150°F jacket temperature the continuous operation limit was 40%. With water as an additional additive to nitromethane and alcohol, the limit was about 60%.

(3) Increased fuel consumption in terms of pounds of fuel per indicated horsepower-hour resulted when nitromethane was used as an additive to a fuel. However, an increase in thermal efficiency was also a result of the addition of nitromethane. This apparent divergence is due to the relatively low heating value of nitromethane.

(4) Considerable mixture enrichment is necessary in order to utilize the properties of nitromethane at the optimum power-output level because of the shift in the resulting optimum mixture ratio. Compensations for this effect result in wider fuel/air ratio control limits.

(5) Compression ratio appears to have only a small effect on the fuel/air ratio range within which pre-ignition can be expected.

(6) More benefit can be derived by inclusion of nitromethane in alcohol than in hydrocarbon fuels.

(7) The increase in power from nitromethane can be accounted for by the increased specific energy of the fuel/air mixture.

British Industrial Developments

Helicopter Test-Tower

To further the development of helicopter power units constructed by D. Napier & Son Ltd., of Acton, London, W.3, a special test-tower has been built at the Company's Flight Development Establishment at Luton, Beds, on which the operation of a complete engine installation can be investigated and the control system thoroughly checked in conjunction with the helicopter rotors for which the power unit has been designed. The test-tower (Fig. 1) has been designed primarily for the Napier Oryx turbo-gas generator, the Eland propeller-turbine installation for the Fairey Rotodyne, and the Gazelle free-turbine engine, although it can be used to carry out fundamental research on similar engines for future helicopter propulsion.

Situated below ground level, the test-site has a basic diameter of 130 ft, surrounded by an embankment rising to a height of 25 ft, additional protection being provided by a steel wire screen supported on pylons. The test-tower itself, consisting of a pyramid-shaped steel structure, is designed to withstand a maximum lift force of 100,000 lb, plus 2800 shp, from each of two engines and propellers, the top section of the structure being detachable to accommodate interchangeable structures for various configurations. A 2000-gal fuel tank suitable for wide-cut gasoline or kerosene is installed outside the test area, the tank embodying a booster pump to provide a 10-psi fuel feed to the engines under test. The test runs are conducted from an observation test-house situated just outside the protective wire screen, controls and instrumentation being provided for two engines. Comprehensive recording equipment is also installed, to permit extensive development to be carried out on present and future installations.

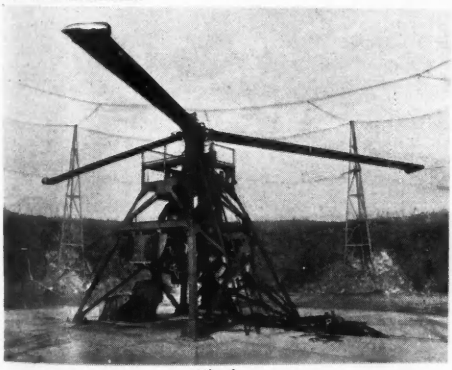

Fig. 1.

The test-tower is at present operating with an installation representative of the Hunting Percival P.74 helicopter propulsion unit, consisting of a pair of Oryx engines, mounted one at each side of the lower fuselage section, the gases being lead by " trouser-leg " ducts into a junction at the rotor head. The entire engine installation is inclined to the horizontal, representative of its normal flight angle, whilst the rotor head is mounted vertically on the test-tower. A gas-spill valve is located in each duct immediately above the engine, permitting the gas to be by-passed during starting and ground running. The rotor head embodies an auxiliary power drive for transmitting up to 20 hp to an accessories gearbox, which also incorporates the mechanism for the rotor brake. Oil systems are self-contained for each engine, and fire precautions include a normal Graviner-type fire-extinguisher system built into each engine installation. In addition, an extra cold-air feed, which could be supplied by the engines in the aircraft, is provided from an electric blower, to determine the amount of cooling required by the oil contained in the rotor head, should this prove necessary.

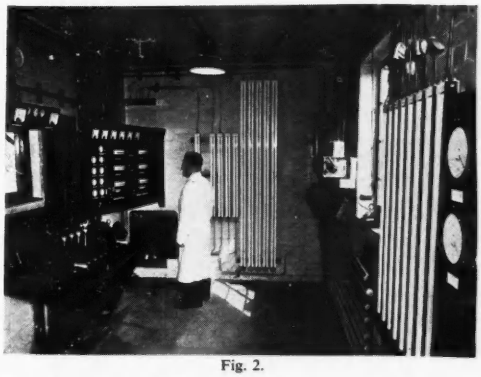

Fig. 2.

From inside the test-house (Fig. 2), each engine is controlled by two levers, throttle and gas-spill valve, special Teleflex controls running underground to the test-tower. Two additional levers control the rotor-head brake and the collective pitch of the rotor blades, cyclic pitch being preset and locked.

Multi-Electrode Spot-Welding Plant

A new multiple-electrode spot-welding plant, the " Permutation " welder, has been designed and manufactured by Sciaky Electric Welding Machines Limited, of Slough, Bucks, for the purpose of spot-welding large sheet-metal assemblies. The principle is to utilize the advantages of multiple-electrode machines to relatively small-scale production, without incurring high capital costs, and at the same time to show large economy over the more conventional method of using portable spot-welding machines and guns making one spot at a time. Moreover, this machine possesses the advantage of the press multi-welder in that the welds are positioned by the machine and not left to the judgment of the operator.

For the job in question, the welding of a commercial-vehicle floor to its chassis, instead of using a separate electrode for each spot weld (in this case over 500 welds), two machines were designed, one to weld the chassis cross-members to the floor (310 welds), and the other to weld longitudinal members to the floor (204 welds).

The first machine consists of a heavy fabricated mild-steel frame and a moving beam, which carries the six transformers and the twelve air-operated welding heads. The beam traverses the width of the floor in increments of 1¾ in. by means of a gearing mechanism, so that twelve welds on the " series " principle are produced at each stationary position of the beam, which inches across in 38 sequences. As the series principle is used, the 500 bottom or back-up electrodes are used only to conduct the welding current from one pair of electrodes to the other. The compressed-air supply to the twelve welding heads is under the control of six independent electro-valves, each with its reducing valve and gauge. Six commutator bars are provided, with either conducting or non-conducting buttons, which are arranged to coincide with the welds required. Consequently, along some of

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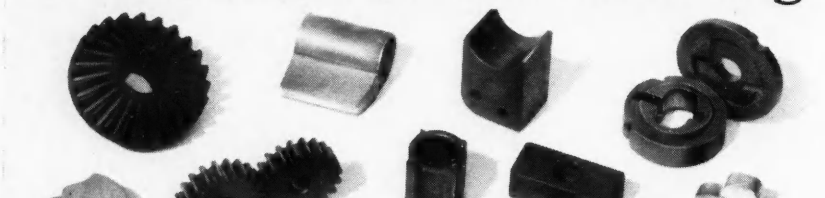

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the rows where the whole twelve welds are not required, the desired number can be selected by fitting the appropriate buttons to the commutator bars. The duration of welding-current flow is controlled by Sciaky timers, while the primary current is switched by ignitron contactor units.

When the spot-welding of the floor members to the chassis cross-members has been completed, the partly welded unit is moved from the first machine to the second, where the remaining welds are made between the floor and the chassis side-members. The system of operation of the two machines is similar but, in the case of the second machine, four welds are made, two per station to each of the long side-members. Once the cycle of operations is initiated, both machines operate entirely automatically, and through a system of limit switches the plant is automatically shut down when the welding has been completed. As both machines are operating at the same time, the time to complete a floor assembly is the speed of the slower of the two operations, and the production schedule for this job, consisting of 514 welds, can be based on 12 per hour. In all, this set-up is capable of 664 welds on the same time basis. It should be noted that the capital cost of this kind of equipment, which incidentally can probably be adapted to cater for changes in design of models, is about 25% less than that of that of press multiple-electrode machines for the same job.

The "Kolene" Cleaning Process

Sole rights in the British Isles for the Kolene process have been granted by the Kolene Corporation, of Detroit, Michigan, to Castingite Limited, of Birmingham, who at the moment have one plant in operation for demonstration purposes and jobbing work. In general terms, "Kolene" is a cleaning process, special applications of which include the preparation of bearing backs for subsequent white-metalling ; the removal of core sand, foundry scale, rust, silica, and carbon inclusions from ferrous castings ; paint stripping ; the removal of oxides, rust, grease, carbon, and water-jacket scale from cylinder blocks, heads, etc. ; the removal of residual rubber, carbon black, and lubricants from rubber moulds, and silica scale from glass moulds ; the elimination of degreasing and pickling preparatory to enamelling, electroplating, etc. ; the preparation of ferrous metals for bonding to rubber ; and the descaling of stainless-steel strip. In the U.S.A. and in Europe, many manufacturers are employing the Kolene process in these applications.

In the cleaning of iron and steel castings, sand and scale removal is accomplished in a bath of Kolene No. 4 salt, which is a hygroscopic alkali base containing neutral salts which act catalytically when activated electrically. It is used as a fused salt, which is completely water-soluble. The chemical reactions in the bath are produced and controlled electrically, electrical energy for activation being supplied by a d.c. source of from 6 to 8 V and of suitable amperage for the size and volume of work to be processed. One lead from the d.c. source is connected to the tank containing the Kolene No. 4 salt bath, while the other lead is connected to the work-basket or fixture immersed in the bath, so that the work forms the cathode. As a result, reducing members are formed in the bath at the surface of the work, and sand, scale, rust, and other oxides are removed, producing a metallurgically clean surface. The equipment required for cleaning castings by the Kolene process is housed in a single unit, which consists of a Kolene tank, a cold-rinse tank, a hot-water-rinse tank, and an adequately ventilated hood. A typical unit of this type is illustrated. The Kolene tank can be heated by any suitable method, and is also provided with means of supplying direct current to the bath.

The Kolene process is adaptable to every type of operation, large or small ; furthermore, it can be set up as a separate operation, or it can be incorporated as part of an automation system. Thus, for example, in the U.S.A., units have been designed with special conveyor installations, some of which are capable of handling completely automatically up to 6 tons of castings per hour. Even with small batch-type units, it is possible to process up to 500 lb of castings per hour.

As already stated, the Kolene process is also used extensively for preparing bearing backs prior to white-metalling. Similar principles also apply to silver-soldering. In this connection, it should be noted that, when the process is used exclusively for cleaning, the reduction cycle, in which the work is negative, i.e., the cathode, is used ; in preparing work prior to tinning, however, an oxidation cycle, in which the work is positive, i.e., the anode, is employed. In general, then, the reduction cycle is used for the removal of scales, rust, oxides, and sand inclusions, while the oxidation cycle is used for the removal of oils, greases, organic materials, sulphur, phosphorus, manganese, graphite, and carbon. Change-over from one cycle to the other is easily effected by a switch while the work is still in the salt bath.

For paint stripping, basically the same process is used, but the salts are of a different chemical composition. Similarly, in the descaling of stainless-steel strip, a different type of salt is used.

Problems of Electro-Hydraulic Controls for Machine Tools

(*Continued from page 290*)

delivery, so that complete filling without back-pressure is hardly possible at high piston speeds when oil viscosity is high. Moreover, in the closed cycle the pressure oil rapidly reaches its working temperature, particularly in winter, and the operating temperature in the tank remains nearly constant, so that thermal expansions are virtually negligible. The small quantity supplied from the tank is fully sufficient, as shown by experience, for the renewal of the pressure oil in the circuit. Operation of the hydraulic motors is also more positive, since overspeeding of the motor is not normally possible in this case. In view of these and other factors, it is not always easy to reach a decision regarding the type of cycle to be adopted.

Finally, the hydraulic motor, of the type shown in Fig. 4 or with simpler features (e.g., a swashplate with a circular toothed sector actuated by a rack, and no disc-type couplings), can be combined with the displacement control pump shown in Fig. 1 and a further solenoid valve into a single closed-cycle, packaged type of electro-hydraulic control unit, provided with a coupling flange for fitting to the machine tool.

(*To be concluded*)

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(P10004)

Universal Oil Additive

A new oil additive, with remarkable anti-friction properties and suitable for addition to all types of oils, including automotive and cutting oils, greases, etc., is announced by United Lubricants Limited, of South Kensington, London, S.W.7. The new product, designated Dextrol Concentrate 905, owes its anti-friction properties to its exceptional adherence combined with its ability to penetrate into and to fill up minute pores and crevices. In addition, it is non-toxic, non-inflammable, and non-corrosive, has negligible volatility, is readily miscible in vegetable and mineral oils, trichlorethylene, hydrocarbons in general, etc. and is stable and impervious to all acids and alkalis.

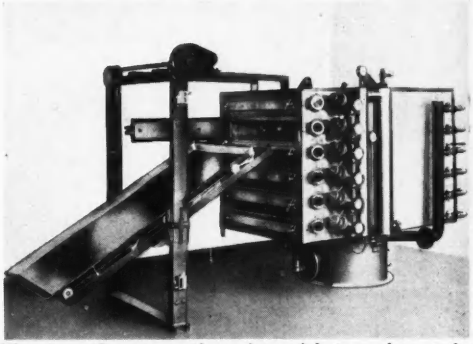
Friction tests were carried out by members of the editorial staff of this journal on various oils, i.e., automotive, cutting, and spindle oils, using a modified Timken test apparatus, in which a cylindrical steel testpiece is pressed against a hardened-steel disc of about 1¼ in. in diameter, pressure being applied and measured with a torque-wrench, and an ammeter being used as a comparator. In all cases, it was found that, without the additive, after 20 sec at a pressure between 90 and 100 lb the amperage rose from its free-running value of 1·15 A to between 1·9 and 2·2 A, with pronounced wear on the testpiece, while the pressure required for actual seizure varied between 100 and 120 lb. With an admixture to the oil of from 5 to 10% additive, the amperage after 20 sec at a pressure between 90 and 100 lb was in all cases about 1·25 A (a negligible increase), with virtually no wear, while the pressure required for seizure rose to the very high figure of between 400 and 650 lb, depending on the oil used.

While it is true that the surface speed in this type of test is comparatively low (about 90 fpm), it should be pointed out that comparative tests involving much higher surface speeds are stated to have been carried out on a number of machine tools in threading, drilling, broaching, and forming operations, and by jet-engine manufacturers and by British Railways, and that in all cases their preliminary reports have been highly satisfactory. Furthermore, it is stated that two standard light cars have been subjected to preliminary tests involving the use of identical crankcase oils, with and without the additive. After running for a few miles, the sumps of both cars were drained, when it was found that the car without the additive ran for only an additional two miles before complete seizure. On the other hand, the adherence and anti-friction properties of the additive which had been used in the second car were such that no signs of seizure occurred even after an additional twenty miles running, when the test was discontinued. It is hoped to hold a similar test, in public and under strictly controlled conditions, within two or three months.

Vacuum Shelf Dryers

A new type of vacuum shelf dryer, with a greatly improved thermal conductivity compared with conventional machines, is now being manufactured in Great Britain by the Calmic Engineering Co. Ltd., of Crewe, Cheshire, under licence from the A.L.A. Company, of Taastrup, Copenhagen, Denmark. This machine, which is capable of drying in the absence of air and light a wide range of materials, including pharmaceutical products, paint pigments, food and vegetable extracts, chemicals, etc., uses steam-jacketed trays, the steam being at subatmospheric pressure.

Because each tray is individually compartmented, operation is semi-continuous, approximately 29 in. Hg absolute being reached within five minutes of closing the doors. Rapid, even drying at low temperatures (down to 95°F for practical purposes) is assured, with a normal evaporation rate of about 2 lb per sq ft per hour with water only, and an efficiency of from 1·1 to 1·3 lb of steam per pound of moisture evaporated. In operation, a cylindrical chamber under the dryer is partly filled with water and partly with sub-atmospheric steam, live steam being permitted to enter this chamber under the control of a thermostat, which is so disposed as to control the temperature of the steam leaving the chamber before it passes through a pipe to valves at the rear of the machine.



The steam then passes through special stop-valves at the back of each compartment, these valves being so arranged that no steam can pass unless the tray is inserted into the oven. Steam passes into the jacket of the tray when the latter is in position, and leaves the tray either as steam or condensate through a small nozzle. This nozzle discharges immediately into the opening of an appropriate vacuum valve, whence steam and condensate, together with the vapours from the material being dried, pass through a water-sprayed condenser to a vacuum pump. The top and bottom of each compartment are also heated by means of steam coils, so as to avoid condensation during the drying process.

This type of dryer is normally fitted with trays of 3 ft × 6 ft, and can be supplied with any number from 1 to 6 trays per complete machine (the 6-tray model is illustrated). However, a small pilot-plant machine, with a single steam-jacketed tray of 3 sq ft, is also available. Rapid and economical loading and unloading of the trays is effected by means of a simple elevator, eliminating damage to the trays and facilitating their replacement.

Thermodynamic Aspects of Nuclear Power Stations

(*Concluded from page 286*)

isothermal heat exchange can be effected in the reactor (with mercury or some other similar medium), because the highest temperature level imposed by the reactor is at the moment far below the upper temperature limit imposed by the materials used. If the secondary fluid is also mercury, this solution will involve considerable research, as no superheating has as yet been applied in mercury-vapour turbines.

In conclusion, it may be stated that heat engineers are confronted with two important problems in the development of nuclear power plants. The first of these is to determine an ideal cycle and to stipulate the requirements of the best working medium to be employed in that cycle ; the second problem is to find the ideal combination of nuclear power plants with the use of conventional fuels. Finally, it should be pointed out that the most appropriate solutions will require more complicated equipment than that so far employed. There is no doubt, however, that the reactor part of a nuclear power plant will in any case involve unconventional designs and processes, and there is no reason why the power-conversion system itself may not also differ from conventional systems.

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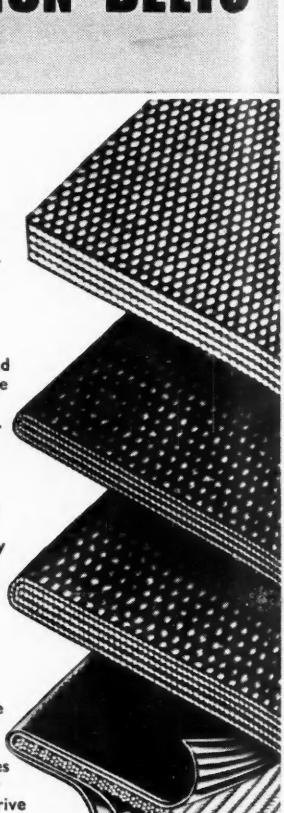

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CLASSIFIED ABSTRACTS

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CORROSION

The Prediction of Corrosion Resistance by Microscopic Examination.

By J. H. SCOTT. (From *Metal Progress, U.S.A.*, Vol. 69, No. 3, March 1956, pp. 79–80, 3 illustrations.)

A MAJOR problem in the production of stainless-steel plates is the measurement and control of corrosion resistance. Usually, samples from each size of plate and from each heat must be tested in boiling nitric acid for five 48-hr periods, the entire test cycle normally taking from two to three weeks to complete. With the object of shortening such tests, Streicher described in 1953 a simple, rapid test for screening stainless-steel plates by microscopic examination of specimens electrolytically etched in 10% oxalic acid. For types 304 and 304 L, if any grain is found to be surrounded by a carbide formation, the material must be subjected to the nitric acid test ; however, if carbides are present but do not surround any grain, the material is classed as a dual structure and is considered to pass the test, as does a structure with no carbide formation, which is rated as a step structure.

The author used the Streicher test on twenty samples of type 304 L stainless steel, but found that only a small percentage of the material was acceptable, although the same samples subjected to the nitric acid test were all satisfactory, with corrosion rates well below the specified maximum rate of 0·002 in. per month.

In consequence of these results, an additional fifty samples of type 304 L stainless steel were prepared, using the electrolytic oxalic acid procedure, but, instead of determining only whether any surrounded grains were present, a complete study was made of each sample. The gauge, grain size, surface condition, number of grains ditched in a given area, and the general amount of ditched structure were all recorded, and the samples were also classified as to whether they had a ditch, dual, or step structure. Once again, only a very low percentage passed the one-grain-surrounded criterion.

With the information gained in this survey, two-hundred additional samples were examined and rated in two ways, in which 20 plates were passed by the Streicher method and 159 were passed using the prediction system based on a thorough examination of the sample. Of the remaining samples, 6 were predicted to fail the nitric acid test, and 15 were rated as questionable. The results were most gratifying, as all those samples which had been predicted to pass did actually pass the boiling nitric acid test with low corrosion rates. Four of the six predicted failures did, in fact, occur, i.e., they had corrosion rates of over 0·002 in. per month. Of the 15 questionable plates, only two failed, but most of them had corrosion rates in excess of 0·0012 in. per month.

This system is now being applied by the author as a standard production procedure to all type 304 L stainless steel requiring corrosion tests. Admittedly, much more experience is required for this modified test than for the Streicher test, but it has been found that it takes only a week to train a technician with previous microscopic experience to carry out the prediction test satisfactorily. For training, use is made of a series of specimens taken from corrosion-tested plates representing all the structures which will be encountered in production samples.

The only material so far used in the modified test is type 304 L in plate form. Other forms of type 304 L, and also a number of samples of type 304 and type 316, have been examined, but enough samples have not yet been checked to recommend adoption of the modified test.

ELECTRICAL INSULATION

A Statistical Method of Predicting Insulation Life from Experimental Data.

By W. H. HORTON. (From *Power Apparatus and Systems (A.I.E.E.), U.S.A.*, No. 24, June 1956, pp. 405–410, 2 illustrations.)

INSULATION systems in 5-hp, 440-V, 3-phase squirrel-cage motors have been evaluated by estimating the functional relationship between insulation life and operating conditions. The experimental data from which the functional relationship was estimated were obtained by constructing several motors with the desired insulation system and then ageing them under accelerated conditions until failure, ageing being accomplished by using alternate periods of humidification at room temperature and operation at high temperature. These periods of humidification and high temperature (175 to 275°C) are necessary, if experimental data on the life of the insulation are to be obtained in a reasonable length of time.

The purpose of this paper is to present the analytical method or the statistical technique used to evaluate the resulting experimental data. In this connection, when the data on insulating life have been obtained under different operating conditions, the problem is to evaluate the insulation system in terms of its suitability for use in motors. The technique by which this evaluation is achieved is known as regression analysis, which is concerned with the relationship between two or more variables, in this case between insulation life and operating conditions. This technique not only answers the question as to how well the assumed relationship holds, but also furnishes the parameters for expressing the relationship in mathematical form.

The importance of this technique in the evaluation of insulation life is now well recognized and recommended. However, it should be remembered that the estimated relationship is valid only over the range of the independent variable used to calculate the life. Extrapolation is definitely unwise, except when there is a sound theoretical basis.

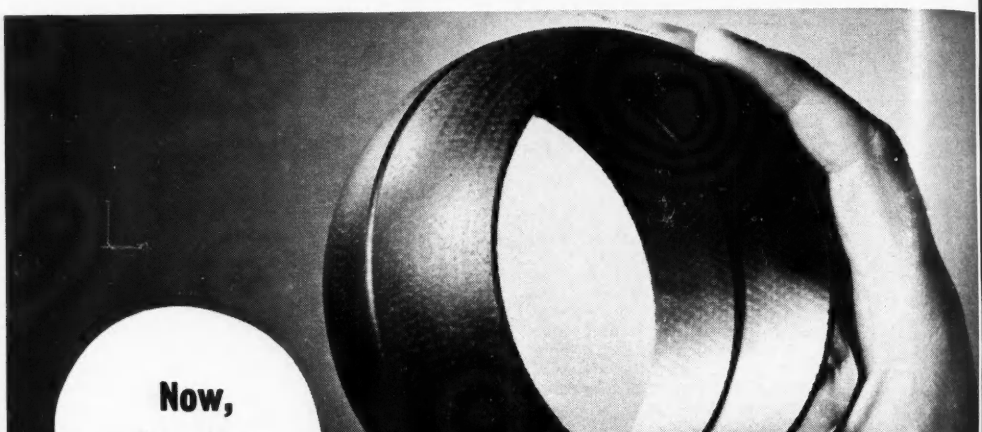
FLOW MECHANICS

An Approximate Method of Calculating Three-Dimensional Compressible Flow in Axial Turbomachines.

By C. O. HOLMQUIST and W. D. RANNIE. (From *Journal of the Aeronautical Sciences, U.S.A.*, Vol. 23, No. 6, June 1956, pp. 543–556, 582, 7 illustrations.)

IN the modern aircraft gas turbine, the flow is necessarily in the transonic range for two reasons, i.e., to keep the weight and size of the machine at a minimum, and to fit the mass flow and pressure ratio of the compressor. Earlier turbojet engines had single-stage transonic turbines, but present engines employ multi-stage turbines with rapid channel divergence, in order to use effectively the increased pressure ratios and to keep the axial velocities compatible with the blade speed. In these types of machines, the flow at the mean blade height is mainly axial, and the aspect ratio of the blades is usually above unity for weight-saving considerations.

The two principal existing methods of calculating axially symmetrical compressible flow in turbomachines are a simplified one-dimensional analysis, and numerical methods using the complete or linearized flow equations. The first method is not satisfactory for multi-stage turbines with appreciable wall divergence ; the second is very tedious and time-consuming. The purpose of the investigation described in this paper is to extend the



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approximate methods, successfully used in calculating incompressible flow in compressors with constant blade height, to the analysis of compressible flow in turbomachines with variable blade height. Assuming that the blades can be completely defined by the exit flow angle and neglecting the influence of downstream blades, the analysis is made considering the flow between successive rows only.

With these restrictions, subsonic and isentropic supersonic flow patterns can be determined for arbitrary boundary shapes of compressors and turbines, provided that separation does not occur. Average losses can be accounted for by the use of a polytropic law, and the effect of radial variations in stagnation temperature can be included without difficulty. Examples are given illustrating the flexibility and practical value of the iteration method which has been developed and the rapid convergence of successive solutions.

METALS FATIGUE

Importance of the Surface Effect on the Initiation of Fatigue Cracks.

By O. LISSNER. (From *Jernkontorets Annaler, Sweden*, Vol. 140, No. 5, 1956, pp. 360–372, 4 illustrations.)

THE fatigue experiments described in this paper were carried out on three carbon steels and on one quenched and tempered Cr-Ni steel. A surface effect was noted, which appears to contribute to the initiation of fatigue cracks. These fatigue tests were interrupted after a period corresponding to half the average life of a testpiece at the stress applied ; a very thin surface layer was then removed by turning, and the fatigue test was continued. In every case a considerable increase in the time to rupture was obtained. In the carbon steels, ageing was found to contribute to some extent to the effect obtained. On the other hand, the greatest increase in the time to rupture was noted with the Cr-Ni steel, which showed no ageing during the interval between the fatigue-test periods.

The results obtained support a theory by Schaub, in which the mechanism of fatigue involves not only a certain plastic deformation but also chemical reactions, especially between oxygen in the air and the atoms in the surface zone of the metal.

PIEZOELECTRIC CRYSTALS

The Growing of Single Crystals of Barium Titanate.

By J. BENES, V. BEDNAROVA, and S. SAFRATA. (From *Czechoslovak Journal of Physics, Czechoslovakia*, Vol. 6, No. 1, January 1956, pp. 56–64, 5 illustrations.)

THE purpose of this paper is to give a brief summary and appraisal of existing methods of growing barium titanate, together with experiments and methods developed by the authors. According to available data, it is not clear whether the growing of single crystals of barium titanate from its constituents has been successful, the difficulties being caused by stabilization at high temperatures ($BaTiO_3$ melts at 1600°C), the chemical resistance of the crucibles containing the melt, etc.

In analogy with the growing of crystals from aqueous solutions, experiments were therefore carried out in connection with the crystallization of barium titanate from a melt which was produced by dissolving barium titanate in some suitable solvent with a fairly low melting point. For this purpose use was made of either barium chloride, with a melting point of 962°C, or of a mixture of sodium and potassium carbonates, melting at a temperature of about 850°C. If barium titanate is dissolved in these fluxes, the binary or ternary melt solidifies at still lower temperatures. Thus, for molar ratios between the individual constituents, as used by various authors, barium titanate can crystallize from melts at temperatures as low as 700°C. At such temperatures the stabilization and regulation of temperatures are reasonably easy, and the crucibles generally used satisfactorily resist the chemical action of the melts.

Two methods were used for the preparation of the melts. In the first of these, barium titanate in powder form was added to the flux, dissolving it at high temperatures. In the second method, barium titanate was produced in the melt by the chemical action of simpler materials, e.g., barium oxide and titanium oxide, barium carbonate and titanium oxide, or barium carbonate and sodium titanate.

The experiments using barium chloride as a flux gave better results than those using a mixture of sodium and potassium carbonates, as the crystals always possessed a pseudo-cubic structure, were larger, and their growth was considerably more rapid. Nevertheless, the data given on this method must be considered incomplete. The degree of saturation and the changes in saturation produced by the evaporation of the flux and other constituents of the melt play a decisive part in the results of growth. In addition to the initial composition of the molten mixture, as well as the materials used in the crucibles, the maximum temperature, and the cooling rate, it is necessary for the sake of uniformity to give the complete heating cycle, the hold-out at maximum temperature, and the shape of the crucible used.

WELDING

Cathode Instability in Argon Atmospheres.

By H. C. LUDWIG. (From *Applications and Industry (A.I.E.E.), U.S.A.*, No. 23, March 1956, pp. 32–35, 7 illustrations.)

CONSUMABLE steel-electrode arcs in argon atmospheres of controlled impurity possess a type of cathode instability which is affected by electrical, chemical, and geometrical parameters. A study of this cathode instability and the accompanying fluctuations in arc voltage and current have been made, and it is the purpose of this paper to discuss these manifestations as related to the welding of structural carbon steel.

Cathode instability, observed as a wandering of the arc flame over the electrically negative terminal of the arc, was previously studied by Tanberg for arcs contained in vacua of a few microns of mercury. Tanberg concluded from these experiments that the arc potential increased because part of the ionized vapour emitted from the cathode was directed away from the anode, or was unable to make a direct path to the anode. The same phenomenon has more recently been found by the author to appear with consumable electrode arcs in very pure argon up to approximately 1 atm pressure. In both cases, one or another essentially uniform arc potential, intermediate between short- and open-circuit conditions, was found to exist intermittently for varying periods.

The cathode wandering observed in this study is defined as an extension of the arc-cathode flame above the tip of the consumed electrode when using straight polarity (electrode negative) or a spreading of the arc-cathode flame on the workpiece when using reverse polarity (workpiece negative). Magnetic oscillographic records taken during these periods of arc irregularity show that two fairly uniform arc operating voltage conditions exist. These are intermediate in magnitude between arc short-circuit and open-circuit conditions. The percentage of time in which voltage rises to the higher values decreases with increasing current for straight polarity. With reverse polarity, the arc voltage remains at a nearly constant value until some apparently critical value of current is used, whereupon the voltage rises to a higher operating value. It is unlikely that this condition will occur in practical welding because of the usual presence of relatively large quantities of impurities on the production workpieces.

Cathode instability of the arc is influenced by arc polarity, geometric parameters, obstruction of ionized arc vapour, and the relative accessibility of surface impurities on the cathode terminal. Arc-gas turbulence, caused by cathode instability and arc interruptions, results in mixing gaseous nitrogen into the arc stream, causing weld porosity.

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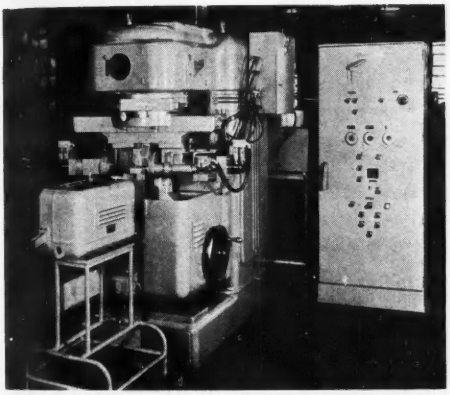
AUTOMATIC UNDERPASS GEAR-SHAVING MACHINE

Capable of automatically finishing gears at a rate of 260 per hour, a new underpass gear-finishing machine designated " Gear-O-Mation ", has recently been developed by the Michigan Tool Company, of Detroit, Michigan. The complete unit consists of the underpass shaver with a vibrating hopper feed and automatic loading, a 3-way probe-type gear classifier, and a control panel. In addition to controlling the operation of the machine, the control panel counts gears of the correct size and keeps track of oversize or undersize gears on a basis both of percentage of production and total count. A feedback system actuated by the gear classifier through the control panel automatically corrects centre distance when gears are undersize or oversize. If this condition persists, the machine shuts down automatically for the required corrections.



The outside diameter on the stub arbors is held between 0·6873 and 0·6875 in., giving a light press fit between the gear bore and stub arbors when the gear is being shaved. A pneumatic cylinder operating the headstock centre is 6 in. in diameter, while the tailstock cylinder is 4 in. in diameter. When the gear is loaded, the headstock centre, powered by the larger cylinder, bottoms against a stop when its stub arbor enters the bore of the gear. The smaller tailstock cylinder does not bottom, but exerts full pressure on the headstock stub arbor. Both stub arbors are instantaneously withdrawn after the gear is shaved. This set-up makes possible consistent accuracy of the shaved gears. After the gears are shaved, they pass through a chute to the 3-way gear selector, with gears of correct size passing straight through. Any undersize or oversize gears are diverted, each being counted by the control panel. This quality-control arrangement, in conjunction with the feedback system, checks every shaved gear for size and gives maximum assurance that every gear will be within specified size tolerances.

ELECTRONIC COMPUTER WITH FERRITE CORED INDUCTOR

Stated to revolutionize the present concept of electronic computers and date-processing machines by introducing a new low level of size and price, the Decca CI computer, developed by Decca Radar Ltd., of London, S.W.9, and shown at the recent Physical Society Exhibition, is built on entirely new principles. This computer employs a new component, a ferrite cored inductor, and as such is the first core-operated computer in the world.

In the Decca CI, the magnetic cores are used to perform not only storage and control functions but also arithmetical operations. Hitherto, computers of similar characteristics to the Decca CI have used either thermionic or gas-filled valves for these arithmetical circuits. The cores used in the new computer are ring-shaped and are only 2 mm in diameter. Consequently, the power required to operate them is very low and is provided by a small number of thermionic-valve pulse generators. In combination, these advantages lead to a lowering of the power demand and heat output, and to an improvement in reliability, combined with a reduction in cost.

The Decca CI computer is a high-speed serial-digit computer intended primarily for computation on scientific problems. Input information is fed to the machine by punched tape prepared on a teleprinter, which simultaneously prepares a copy in plain language. Programme input is in the form of words, each of 40 binary digits. Each word specifies two operations and includes the address of the next instruction. For arithmetical operations a decimal notation is adopted, and a word then consists of a digit indicating the sign, followed by a 9-decimal digit word. Information within the computer can be stored either on a 63-channel magnetic drum or in magnetic-core shift registers when quick access is required. A novel technique is used in the magnetic drum store, on which the digit rate is three times that of the computer itself. The access time to the drum is thus one third of what it would be if the drum rotated at a speed appropriate to a 1 : 1 digit rate. Alternative output circuits permit either a teleprinter of an electric typewriter to be used to print the answer. A cathode-ray-tube monitor provides comprehensive checking facilities. The monitor is also capable of generating numbers on switches for test purposes. The power requirement is 6kVA, 415V, 3-phase. The machine comprises two cabinets, each 6 ft 3 in. high by 2 ft 11 in. square, and the operator's desk on which rests the teleprinter or electric typewriter.

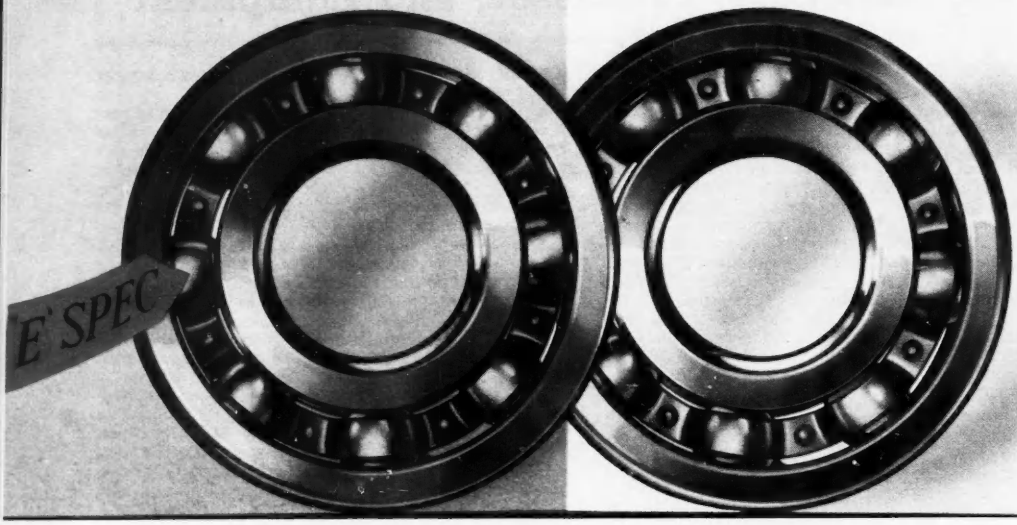
VERTICAL BORING AND TURNING MILL

Features of the new heavy-duty vertical boring and turning mill recently developed by the Giddings & Lewis Machine Tool Company, of Fond du Lac, Wisconsin, include specially designed box-type construction housings and a completely new extra-heavy bed and table unit designed to support table loads up to 55 tons. Two precision anti-friction table tracks support the work loads. One bearing is nearly 8 ft in diameter, while a large tapered roller bearing at the centre of the table prevents misalignment of table or work due to radial thrust. The machine is built for an extra-high speed range for the best use of modern cutting tools, i.e., 0·7 to 60 rpm, with an electronically controlled duplicator which provides two-dimensional tracing.

Incorporated in the design is a constant surface-speed attachment as well as a constant chip-thickness control. The machine also features a right- and left-hand ram-type swivelling rail head, and a right-hand side head with independent motor traverse. A constant surface-speed indicator, as part of the constant surface speed control, is also fitted. Finally, for operating convenience, a direct-reading horse-power indicator is incorporated in the design.

The diameter of the table is 96 in.; the swing above the side head is 103 in.; the height under the rail, which is clamped to the housings electrically, is 86 in.; and the swivelling rail heads have a 52-in. travel to the rams, which

PENNY PLAIN



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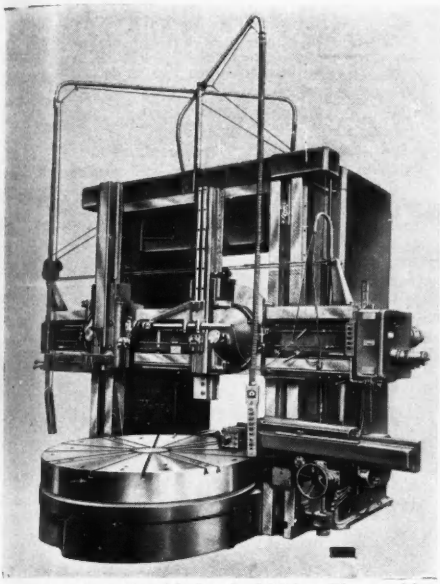


have a travel on the side head of 36 in. The machine is powered by a 75-hp motor, controlled to give a wide range of table speeds in conjunction with a single gear shift.

ELECTRO-HYDRAULIC FLANGING PRESS

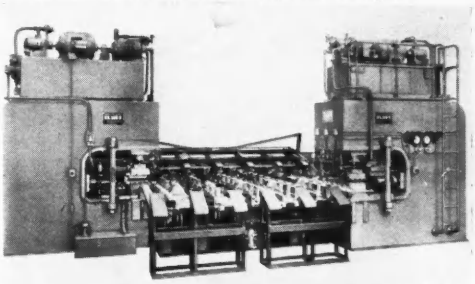
The new electro-hydraulic flanging press produced by T. B. Pearson & Sons Ltd., of Newcastle upon Tyne, incorporates two unique features connected with the hydraulic system: Firstly, there is an adjustable relief valve enabling the pressure most suited to the work in hand to be preselected, thus preventing any distortion of plates because of excessive pressure. Secondly, the valve system incorporated within the pump provides a large volume of hydraulic fluid at low pressure for fast approach speeds of the pressure beam, but switches automatically to high pressure when required.

Four models of the press are available, i.e., 120, 200, 300, and 500 tons capacity, and in addition to normal plate bending and flanging work, they can be used in the manufacture of special profiles. The press is under the operator's control throughout. The downward movement can be halted at any point, and when the foot-pedal is released the pressure beam returns to the top of its stroke—an important safety feature. The electro-hydraulic system gives a high degree of accuracy, with controls which are light and sensitive to operate. The system also provides maximum pressure at every point of the stroke for as long as required.

The machine is of welded steel construction to give maximum strength. The pressure beam is a heavy steel slab reinforced against lateral deflection. The travel of the beam can be adjusted to the requirements of the work in hand, reducing the time per stroke to the essential minimum. The hydraulic system is simple and efficient, consisting of a multi-cylinder radial-type pump directly coupled to a continuously rated squirrel-cage electric motor, an adjustable relief valve, control valve, and the two main cylinders. The control valve, being hydraulically balanced, ensures a light, sensitive control of the pressure beam. Foot-operation leaves the operator's hands free for easier handling of plates. The return stroke of the pressure beam is operated by an entirely independent self-contained system, powered by a hydro-pneumatic accumulator. This gives a quick return stroke without any effort on the part of the operator.

AUTOMATIC HYDRAULIC TUBE-REDUCING PRESS

Fully automatic and employing the latest principles of automation in its design and operation, a new hydraulic tube-reducing press, developed by the Elmes Engineering Division of American Steel Foundries, of Cincinnati, Ohio, removes a piece of tubing stock from a conveyor or a loaded magazine, positions the piece prior to its entering the machine, carries it into a 3-stage work station where the reducing operations are performed, and then removes the finished tube from the machine and deposits it into a tote-box or another conveyor.



The new press is a completely self-contained unit equipped with two "C"-frame stationary ends, each having three 25-ton tube-clamp rams and three 10-ton reducing rams. It is designed to reduce in 12 sec both ends of a steel tube of 2 in. in diameter and 0·062 in. wall thickness from 2 in. to $1\frac{1}{4}$ in. An exclusive feature of the new unit is that tubes from 54 in. to 13 ft 6 in. in length are handled automatically without the need for making any adjustment for different lengths of tubing.

AUTOMATIC SCREW MACHINE WITH HIGH-SPEED REVERSING CLUTCH

A new high-speed automatic screw machine for the production of precision-screw machine parts has been developed by the Brown & Sharpe Manufacturing Company, of Providence, Rhode Island. The machine automatically feeds in the stock, indexes the turret for successive machining operations, and automatically cuts off and discharges the workpiece. High production rates are achieved by spindle speeds up to 3025 rpm and, to provide rapid non-cutting movements as well as fast

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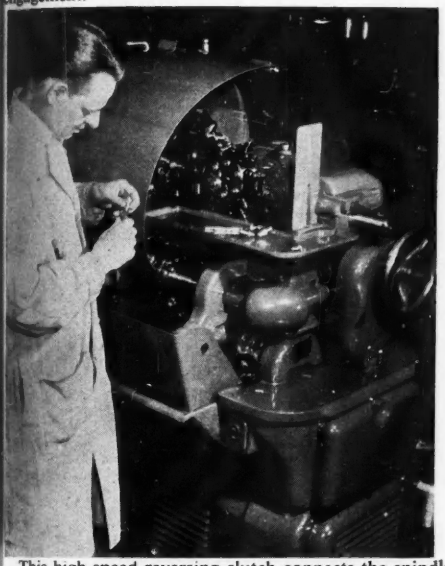
production operations, the spindle is rapidly reversible through a specially designed cone clutch.

In the design of a clutch for this machine, the positive, powerful spindle drive requires the cone clutch to be strong; at the same time, rapid reversal necessitates low inertia, so that the movable clutch element must be comparatively light. The most severe requirement, however, is imposed by the very considerable heat generated in the rapid engagement and disengagement of the clutch. To meet these requirements, the movable clutch cone is constructed of a specially developed moulded phenolic plastic material, consisting of a square-woven cotton fabric impregnated with phenolic resin. This material is then macerated into small flakes, which are subsequently moulded under high pressure and heat. The result is a material which can be subjected to considerable heating without deterioration or warping; in addition, it bonds well to metal, so that weight is further reduced and strength increased by moulding the clutch cone directly onto the steel plate which carries it into and out of engagement.

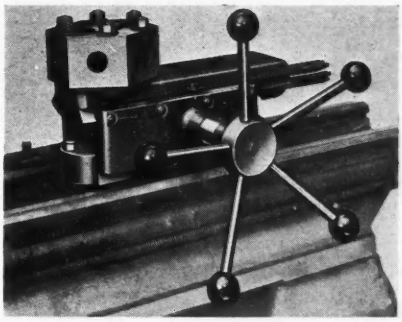


This high-speed reversing clutch connects the spindle to a constant-speed drive in approximately 0·5 sec, and is operated at frequencies as high as once every 3 sec, resulting in operating temperatures up to 250°F. However, even under these severe conditions, smooth, positive clutch action, without deterioration from heat, is consistently provided.

SELF-INDEXING LATHE-BED TURRET

A new type of self-indexing bed turret, for use on most standard lathes swinging from 9 to 12 in., has been developed by Globe Heat-Seal, Inc., of Los Angeles, California. This turret features a robust self-indexing mechanism which is linked to automatic stop rods, which limit stroke length and can be set for any requirement up to the full slide working stroke of 5¼ in., total slide travel being 6 in. The turret is guided in its rotation by a large-diameter integrally cast pilot, which deeply engages a mating bearing in the slide. Flat bearing surfaces between the ram and turret are hand-scraped for close fit. Because of its design, the entire work load is applied to the pilot and flat bearing surfaces, resulting in extreme rigidity and freedom from deflection.

A hold-down bolt applies an adjustable, preloaded pressure against a ball thrust bearing located on the turret base, so that no hold-down handle is required.

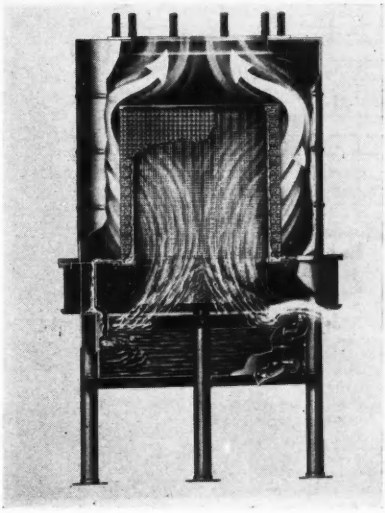


Saddle and ram bearing surfaces are unusually long, and heavy, dovetailed gibs not only provide full support on both sides of the ram but permit easy centralization as wear occurs. The hexagonal turret is provided with flat faces which accommodate flanged tool holders and which may be bored for straight shank tools. The ample turret stock permits boring standard 1-in. holes or even 1¼-in. oversize holes, with no weakening of the walls. Long bars can extend completely through the turret.

Indexing is performed by a spring-loaded tapered pin sliding in a sleeve and engaging a mating tapered bushing in the turret. These parts are of hardened tool steel, finish-ground. The tapers automatically take up for wear and ensure unerring accuracy of location. Other features of the new turret include a calibrated scale showing length of stroke, a tool clearance over the ram of 3½ in. on 9- and 10-in. lathes and 4 in. on 11- and 12-in. lathes, free-wheeling turret action backwards or forwards, and a 5-spoke pilot wheel for extra convenience.

OIL-BATH AIR FILTER

A new oil-bath air filter, combining high efficiency with an extremely low pressure drop which is achieved without any moving parts or outside source of energy, is announced by the Air-Maze Corporation, of Cleveland, Ohio. The new filter, designated LPD, reduces energy requirements, making it possible to eliminate power-consuming motors and all other moving parts, by reversing the conventional oil and air circuit. In the LPD filter, air is drawn in under a weather hood set low on the unit and is directed through an air-flow regulator tube to an



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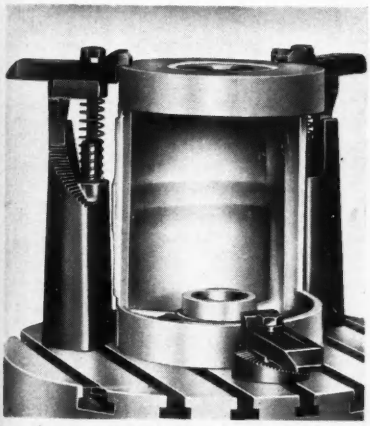
oil-control pan. Here, the air picks up droplets of oil which are carried up through a diffuser cone, where air and oil are thoroughly mixed and the air is scrubbed. The air then passes through the cylindrical filtration element, where dirt particles and oil droplets are removed, permitting only clean, oil-free air to flow to the engine, blower, or compressor. Oil and the dirt it has collected flow down inside the filtration element and through oil-return pipes to the sump, where dirt settles out. Clean oil is metered from the top of the reservoir into the oil-control pan through calibrated holes in the sides of the pan. An unusually large oil reservoir has capacity for large accumulations of dirt, permitting long operation before servicing. To facilitate servicing, a quick-opening drain valve is fitted, and the weather hood and oil sump are arranged for easy disassembly.

The air-flow regulator tube is preset at the factory so that, within a filter's rated capacity range, air velocity will be sufficient to ensure full oil-washing, but will still keep pressure drop low. Tests with a standard air cleaner on fine dust showed a high level or efficiency for the LPD of 97·5% of the dirt arrested. The smallest of the four models recommended for variable-speed engines and compressors has a capacity range from 800 to 3500 cfm, with a pressure drop of from 0·6 in. water-gauge to 4·8 in.; the largest of the models for constant-speed engines and compressors ranges in capacity from 16,500 to 24,000 cfm, with a pressure drop ranging from 1·9 to 3·5 in.

HELICAL CLAMPS

Covering a wide variety of clamping work, the Rockwell helical clamp, announced by the Rockwell Machine Tool Co. Ltd., of London, N.W.2, ensures fast, easy mounting and accurate, simple height adjustment, with a minimum of clamp projection over the workpiece, a two-position strap bringing the clamping force close to the work. Furthermore, each clamp is a complete unit in itself, and it is unnecessary to use a number of loose parts such as bolts, washers, nuts, and blocks of different lengths and heights.



These clamps, a typical example of which is illustrated, feature a helical "staircase", consisting of small steps extending around the axis of the clamping bolt. This staircase supports the lower stepped end of the clamp supporting member, which is arranged for rotary adjustment about the clamping bolt. The supporting clamp carries an off-set clamping strap arranged for longitudinal adjustment in a groove formed in the upper surface of the supporting member. The clamping strap can be reversed by 180 deg. A compression spring between these two members greatly facilitates adjustment to the desired height. The clamps are constructed of high-grade spheroidal precision castings, and the clamping bolt and tubular nut of heat-treated steel. The clamps are available in sixteen sizes, the smallest for clamping workpieces up to 1¾ in. in height, and the largest up to 15½ in.

MAGNETIC VALVE FOR LIQUIDS OR GASES

A new magnetic valve for air, water, light fuel oil, and gas has been developed by Teddington Industrial Equipment Ltd., of Sunbury-on-Thames, Middlesex. The valve is pilot-operated and provides ⅜-in. full-bore flow for liquids up to 150 psi or gases up to 250 psi.

Arranged to open when energized, the valve is fitted with a continuously rated coil and is robustly constructed for industrial use. Particular attention has, however, been given to size and weight, so that it is equally suitable for oil-fired boilers, washing machines, and other domestic appliances.

AUTOMATIC PALLET LOADER

An entirely new low-capacity, fully automatic pallet loader, providing a completely automatic pallet loading system for plants where production rates are moderate and where the complexity of products produced simultaneously is at a minimum, has been produced by the Lamson Corporation, of Syracuse, N.Y. The new loader has a capacity of about 20 cartons a minute and can be justified at a capacity as low as 5 per minute.

The model at present in production is designed to handle pallets up to 48 × 48 in., with a maximum load width, including overhang, of 52 in., and a maximum length of 50 in. The machine can be loaded with pallets one at a time or in stacks. The weight of a load on a pallet is unlimited, since the pallet is set directly on the floor and no weight is carried by the loader. The weight of a layer of cartons has been limited to about 600 lb, but can be increased with moderate revisions. This particular loader will handle sealed cartons with a top diagonal dimension not exceeding 21 in.

The new machine forms the layer in the same manner as the conventional high-speed machine. Loads are received from production onto the feed and accelerator conveyor, which in turn discharges onto the package conveyor. Packages are rammed onto the layer conveyor which is a belt-driven, live-roll conveyor. Once a layer is formed, the control system notifies the transfer head that a layer is complete and ready to be removed. The hoist lowers the head onto the top of the completed layer, and at the same time a closer-bar operates from the side to "snug-up" the layer. The live-roll layer conveyor effects the same action in the other direction. As soon as the transfer head is resting on the layer, a slack-cable switch stops the lowering action and opens the valve controlling a blower which creates a vacuum. When the vacuum has reached a predetermined point, a pressure-switch reverses the head, and the entire layer is raised. The head and layer move laterally until they reach a position directly over the pallet. The head descends and deposits the layer onto the pallet. The slack-cable switch closes the blower valve, which cuts off the vacuum, after which the head is hoisted and returns to repeat the cycle.

Pallets are stacked on either side of the machine and are alternately loaded, i.e., a pallet is loaded completely on one side of the machine, and then the head will shift

You observe that the voltmeter on the incoming supply fluctuates wildly; and that the one on the outgoing supply is quite steady. Look behind the panel and you will see how the trick is done. You will find there an Austinlite series voltage regulator.

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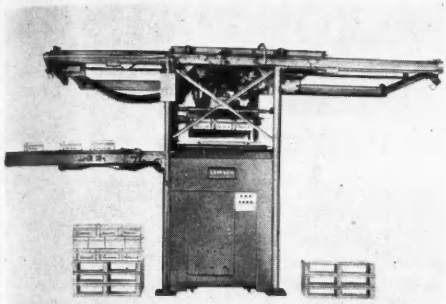
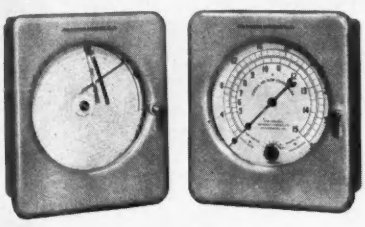


and load a pallet on the opposite side. A system of limit switches is incorporated into the loader, so that it will shut down if the loaded pallets are not removed. The loader, which is equipped with seven electric motors and which requires an air supply of about 2 cfm at 60 to 80 psi, can be changed over rapidly to cartons of a different size by changing the grid of the pick-up head.

CUPOLA BLAST INDICATOR AND RECORDER

The new Thompson cupola blast indicator, announced by the John Thompson Instrument Company Limited, of Ettingshall, Wolverhampton, is designed to supply continuous information on the performance of a furnace by giving a definite warning to the operator should the cupola be working below maximum efficiency, as in the case of slagging up of tuyères, scaffolding or bridging charges, or too deep or too shallow a coke bed. The standard instrument, shown on the right of the illustration, has a graduated circular scale, with an effective length of 20 in., and two pointers, the centre pointer indicating the air flow in cubic feet per minute, and the outer pointer the air pressure in the cupola wind belt. The instrument, which is completely housed in an aluminium casing, is of the flush-panel-mounting type, is dust-proof, and can be easily and quickly installed in such a position as to be under the constant supervision of the cupola operator.



The indicator can also be supplied with an automatic damper-control mechanism, which ensures continual regulation of the oxygen feed to complete combustion at optimum conditions. In addition, it can be fitted with a blow-down attachment, which is put into operation by depressing a switch after the last charge has been added. Furthermore, the instrument has been designed to operate a two-pen recorder (shown on the left of the illustration), thereby providing a complete record of air flow and air pressure throughout the periods when the cupola is in use. Similarly, a "charge-dotting" mechanism can be supplied, which, when installed together with the two-pen recorder, records each furnace charge, providing a complete picture of the working efficiency of the cupola and making a permanent record of all furnace operations.

Gyro-Type Ball Mill

(Concluded from page 274)

TEST RESULTS

A gyro-type ball mill of the above type was built and tested. It was found that the best results were achieved when the mill was operated at the highest attainable speeds and when the ratio of the cylinder speed about its axis to its speed about the transverse, i.e., vertical, axis was between 1 : 1 and 5 : 1. It was also found useful to include some larger and heavier balls among the large number of small balls, since in this way a favourable increase in random motion is obtained.

Photomicrographs of pulverized quartz show that after three minutes running very fine particles were obtained in the gyro-type ball mill, whereas many times larger particles were produced by a conventional ball mill operated under its optimum conditions for the same length of time. After ten minutes running, the gyro-type mill gave extremely fine particles of comparatively similar grain sizes, whereas the conventional mill produced particle sizes varying in the ratio of 25 : 1, with much greater average sizes than the gyro-type mill. These results were also obtained with other substances.

It is considered that the remarkable homogeneity and fineness of the pulverized product are due, as stated, to the use of an increased number of balls of small size in an arrangement which gives them considerable individual values of momentum. However, there is probably also another factor which contributes to these favourable results, i.e., the truly random motion of the balls. Incidentally, this motion is accompanied by a characteristic continuous whirring sound which is clearly audible and different from the periodic non-uniform sound produced by an entire agglomeration of balls in a conventional ball mill.

The number of ball collisions per second, assuming random motion, can be calculated by the relations employed in the kinetic theory of gases. The mean free path L of the balls is given by

$$L = V/\pi N D^2 \sqrt{2}$$

where V = volume of cylinder, N = total number of balls, and D = ball diameter. The gyro-type ball mill built for these first tests has a cylinder volume of about 1000 cm³ and was charged with 2000 balls of 0·5 cm diameter, which occupied about one quarter of the cylinder volume. With these figures, the above equation gives $L = 0{\cdot}5$ cm. On the assumption that the mean speed v of the balls is of the same order as the linear peripheral speed of the cylinder wall, at a cylinder speed of 6000 rpm and for a cylinder diameter of 10 cm, a value of $v = 3000$ cm/sec is obtained; hence, the number of collisions per second n of the balls with each other is

$$n = Nv/(2L) = 6{,}000{,}000$$

Thus, even if a considerably lower value is taken for the mean speed in order to allow for ball impacts against the walls, the number of impacts will be of the order of one million per second. This value exceeds considerably any of the impact frequencies hitherto attained in mechanical disintegrators.

Apart from its main use, i.e., dry milling for the production of flour and fine powders, finely dispersed chemicals, pigments, etc., the gyro-type ball mill can also be employed in wet milling, e.g., for the dispersion of solid substances in liquids or of non-miscible liquids.

Sentinel

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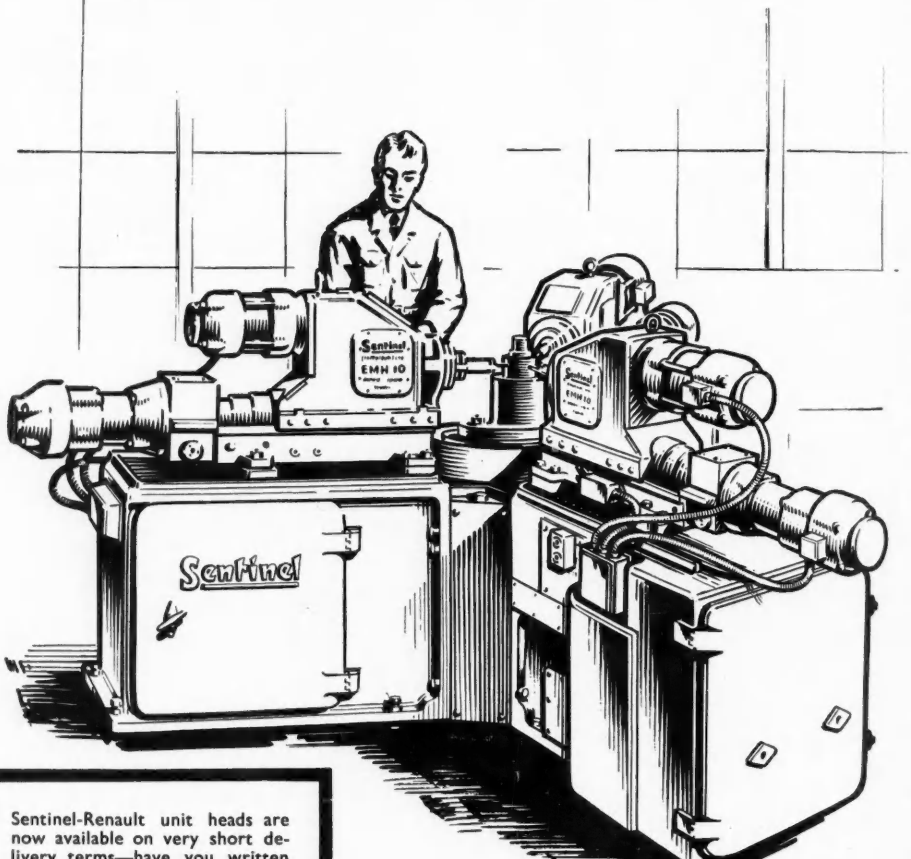
This machine is designed for the simultaneous drilling of three radially positioned holes. A fabricated steel base carries a central fixture, which holds the component for machining. The three Sentinel-Renault unit heads are mounted on standard cast iron bed extensions. The machining cycle is automatic, and is push button controlled from the front of the machine.



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SS/31/354

INTERNATIONAL MACHINE TOOL EXHIBITION, 1956

In our issues for May and June, previews were included of some of the items shown at the International Machine Tool Exhibition, which was held this year between June 22 and July 6. A further selection is given in the following pages.

A comprehensive range of jig-boring, grinding, lapping, and fine-boring machines has been exhibited by **The Newall Engineering Co. Ltd.**, of Peterborough, and includes their Model 2436 (Mark II) production jig borer (Fig. 54), developed for boring and light milling of batch components to precision limits at high output rates. In this model, which has a table capacity of 24 × 36 in., the Newall system of table location by rollers and micrometers has been retained. Principal new features include an increase in quill diameter, to permit the use of a sturdier spindle ; the incorporation of a built-in depth-measuring attachment for accurate control of blind bores ; the provision of four spindle speeds, from 0·002 to 0·008 in., both up and down ; differential clamping of the feed-box, interlocked with elevating-motor controls ; and a main control lever giving fine and coarse hand feed, and up and down power feed.

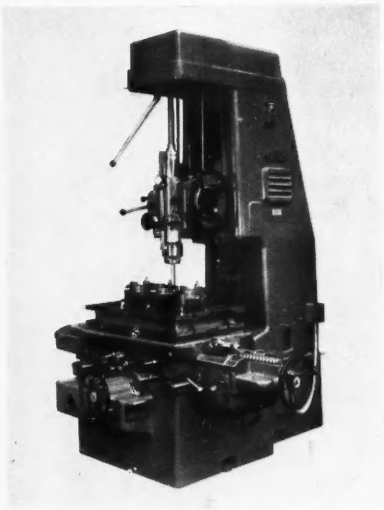


Fig. 54

Also exhibited by Newall was their completely new model OP2436, with the same capacity as the above machine. In this model table location is effected by an optical projection system, designed and manufactured by **Optical Measuring Tools Ltd.**, one of the Newall group of companies. This system incorporates accurately engraved scales calibrated at intervals of 0·05 in. ; images of both scales are projected onto easily readable screens in a fixed console on the bed of the machine and give readings direct to 0·0001 in., or finer by interpolation. Provision is made in the optical system for presetting the coincidence graticule in readiness for a succeeding bore, whilst the jig borer is in operation. The unique feature of the optical system is that it is possible, having set to the workpiece datum, to set the system so that a complete zero reading of both inches and decimals appears on the screen, thereby making it unnecessary for the operator to add in certain fixed measurements to each reading. The setting of the scale line in relationship to the screen is such that a repetitive accuracy of 0·000025 in. is attainable.

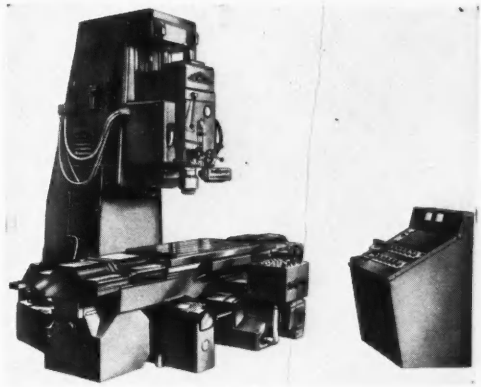
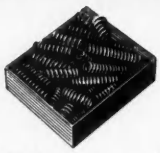


Fig. 55

The largest of the range of Newall jig borers exhibited was their new " Spacematic ", model 2657, which has a table capacity of 24 × 42 in. In this machine (Fig. 55), the spindle nose accepts a large-diameter shank, and the fact that boring bars and heavy milling cutters go straight into the spindle ensures maximum possible rigidity. A 3-speed spindle gearbox gives adequate power at lower speeds, and speed changes are effected by electromagnetic clutches remotely controlled by push-buttons. Milling feeds (¼ to 12 ipm) and rapid traverse (60 ipm) for cross-slide and table are through a d.c. motor and 2-speed gearboxes, these also being used in connection with automatic positioning. The measuring and control system, developed in conjunction with British Thomson-Houston Ltd., of Rugby, consists of measuring bars in which are incorporated reference units accurately spaced at 1-in. intervals. These units are factory-set to a high degree of accuracy, and provision is made for trimming out any residual errors when they are fixed to the machine. An electromagnetic detecting head, positioned by means of a micrometer to the required decimal proportion of 1 in. senses the reference units. The head is capable of detecting errors in position to an accuracy of 0·00002 in. and is entirely independent of fluctuation in electrical supply frequency or voltage. No physical contact exists between detector head and bar ; consequently, no wear can take place.

In addition to their well-known range of rectangular permanent-magnet chucks for use on surface grinders, **James Neill & Company (Sheffield) Limited**, of Sheffield, exhibited their AX 74 model (7 × 4 in. surface), which bridges the gap between their 10 × 5 in. chuck and their minor chuck, and which, when used in conjunction with their " Eclipse " No. 312 swivel angle-plate, provides a

No. 760. 3 doz. Assorted Light Compression Springs 1" to 4" long. 22 to 18 S.W.G., ¼" to ½" diam. 6/6 each.



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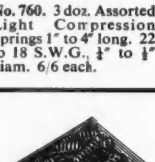

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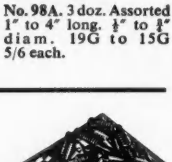

No. 388. ¼ gross Assorted Small Expansion Springs. ¾" to 1¼", 18G to 21G. 9/6 each.

No. 758. Fine Expansion Springs. 1 gross Assorted ¼" to ⅜", ¼" to 2" long, 27 to 20 S.W.G. 15/- each.

No 466. ¼ gross Assorted Small Expansion Springs ⅜" to 1¼" long, 3/32" to 3/16" diam., 21G to 24G. 6/6 each.

No. 1013. 1 gross Small Coil Compression Springs, ⅜" to 1¼" long, 3/32" to 7/16" diam., 24G to 19G. 6/- each.

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swivelling chuck of particularly handy dimensions for dealing with small and intricate workpieces. In addition, a comprehensive range of heavy-duty chucks was shown, further extending the scope of the permanent-magnet chuck in the field of surface grinding, as well as in shaping and horizontal and vertical milling operations. These latter chucks were exhibited either as single or multiple units, with flush ends for mounting in continuous formation into any desired length.

A particularly comprehensive range of "Eclipse" circular magnetic chucks was also featured, the smallest being 4¾ in. in diameter and the largest 12 in. These chucks are supplied with spigot recesses and tapped holes for back plate fixing. In addition, magnetic flotation by means of the "Eclipse" magnetic floater was demonstrated, as an efficient method of facilitating the separation of ferrous sheets for machine feeding or manual handling, while, as an aid to setting up, marking out, or tack welding, the "Eclipse" flux-controlled magnetic holder or the adjustable magnetic clamp was also exhibited.

Other Neill exhibits comprised a full range of "Eclipse" hack-saw blades and frames, as well as many other tools, including angle plates, vee-blocks, clamps, surface gauges, trammel heads, lathe tools, and tool-bit and cutting-off tool holders.

Exhibits by **Heenan & Froude Limited**, of Worcester, included the Heenan "Hydraulic Multiform", an entirely new method of cold strip forming. This machine (Fig. 56), which was shown at the Exhibition for the first time, employs hydraulic operation throughout and, apart from the actual tool-slides themselves, dispenses with mechanical movement, thereby eliminating the drawback of the time taken for setting up with purely mechanical methods of operation. In this connection, it is stated that, with semi-skilled labour, the setting-up time with the new machine is reduced by no less than 90%.

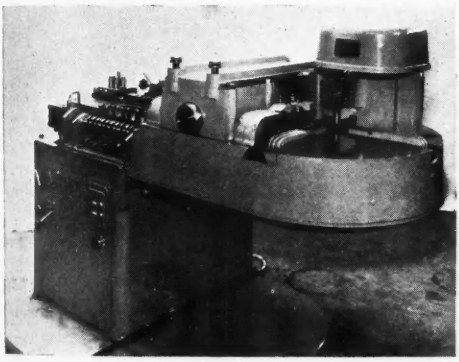

Fig. 56

The principle of operation of the new machine is based on the servo-valve actuated by a master camshaft working on a few pounds pressure, which is converted into the full tonnage of the machine at the operating stations. The master camshaft is situated at the front and is mounted between two centres. The cams actuate small toggle arms, which are, in turn, connected to Bowden-type cables connecting up to the servo-valves. With this arrangement it is possible to have extremely accurate control of the servo-valves with only a very light pressure on the cam faces, thus permitting perfect control of each slide. The cams on the master camshaft are sawn from gauge steel plate and, owing to the very light pressure exerted on them, it is not necessary to use any form of hardening. Altering the movement at any station on the machine can easily be effected merely by filing the cam form whilst the cam is in position on its shaft. A set of cams, complete with shaft and tools, can be removed from the machine and subsequently replaced without any setting up, while still ensuring that the original movements and timing to the feed mechanism, stationary grip, horizontal press, cut-off station, and all forming and vertical stripping slides will be obtained without further adjustment. This permits extremely rapid change-over from one type of production to another with practically no loss of time.

The camshaft is fluid-driven, with an infinite choice of speeds from zero to rated maximum. In addition, the whole unit is of very rugged construction, safe to operate, owing to the absence of external moving parts, and occupies 50% less floor space than its mechanically operated counterpart. Various slide movements can be selected to suit any particular job, or various slides not required may remain stationary, thus accomplishing higher output speeds. Each slide during operation travels only the required distance. The full travel of each slide is not used, unless required for the particular job, thus saving lost time in large reciprocating movements. Each slide has only the required amount of pressure exerted on it, and this is capable of infinite adjustment, so that complete jamming on delicate tools will not result in breakage. When initial setting up is taking place with a new set of cams and tools it is possible to operate each toggle arm manually to assess the travel of that particular slide in relation to the work to be performed.

The whole machine has been designed in streamline form, and the design allows the tool setter to position himself comfortably during tooling up and permits easy access to work clearage.

Among the wide range of equipment exhibited by **B.S.A. Tools Ltd.**, of Kitts Green, Birmingham, the 6DRE 40 Potter and Johnston automatic turret lathe (Fig. 57), which is being built by B.S.A. under licence, is a new machine developed from the basic Potter and Johnston 6D automatic design. This machine has a headstock which is of entirely new and advanced design and which is capable of an output of 40 hp. Both at the front and rear the spindle is mounted in double bearings, the front pair of bearings being preloaded. The design of the spindle is such that accuracy of machining through fast and heavy cuts is at all times assured. Multiple disc clutches, with electro-pneumatic control, are used to effect automatic spindle-speed changes. All gears are of the constant-mesh type, and speed changes can be made between turret faces or while cuts are in progress. As the drive for the turret and cross-slide is taken from the spindle, feed is maintained in inches per spindle revolution, even though spindle speeds are automatically changed. Positive-tooth clutches controlled by electro-pneumatic means effect automatic feed changes.

The control-drum of the machine is also of new design, making step-up easier, faster, and more versatile For convenience during set-up, the dog-operated levers have extensions for hand operation. All automatic func-

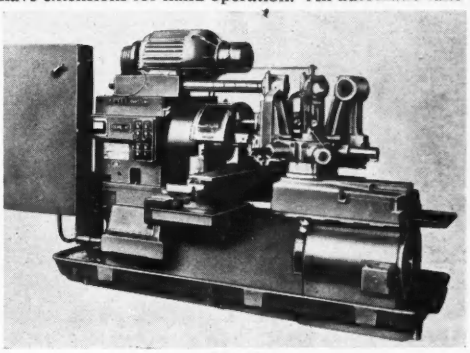

Fig. 57

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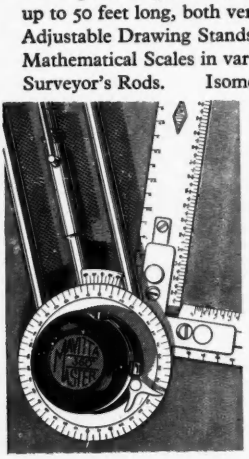

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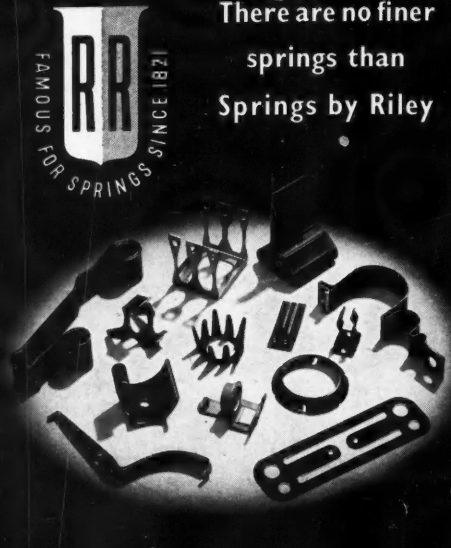

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tions of the machine are taken from the drum and are tabulated on a prominent indicator plate. Cross-slide motion relative to turret motion is obtained via a timing box, through which retiming of relationship (cross-slide and turret) is readily made. The normal set-up provides two cross-slide movements in conjunction with the turret slide for rough and finish facing, grooving, etc., and a third movement whilst the turret dwells in its forward position for operating a slide tool. The cross-slide is adjustable longitudinally on the base ways for correct relation to work held in the chuck. For fast and convenient set-up and operation all slide and spindle motions are controlled from a well-placed push-button panel. Also included in the control panel is a load meter, to permit the use of full power on heavy cuts without any danger of overloading. The turret, which is bored and faced in place on the machine, thus guaranteeing alignment, is automatically released at the start of indexing, and after indexing is automatically clamped and locked before advancement to the feed position.

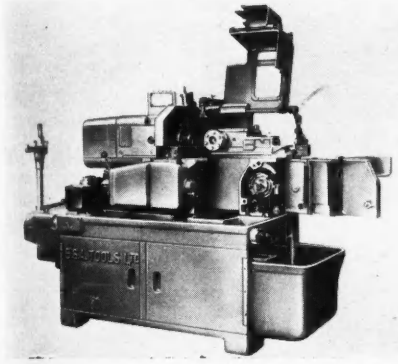


Fig. 58

Another new exhibit was the B.S.A. 68L single-spindle automatic screw machine (Fig. 58), which incorporates many new features and which is the British version, of equivalent capacity, of the well-known B.S.A. 18L metric machine. A one-piece casting forms the base, in which are housed the spindle-drive gearbox, coolant tank, and swarf pan. The body, which is constructed on the open-front principle, is designed to give complete rigidity to the headstock, cross-slides, and turret-slide, thus ensuring vibration-free cutting, accuracy, and a good finish to components. As the work-spindle chain drive is totally enclosed, a plentiful supply of oil may be used, without fear of leakage. In plan, the machine is roughly L-shaped, thereby permitting unimpeded access to the tooling area.

The standard machine is arranged to give two speeds, forward and reverse, or both speeds in the same direction; however, a four-speed gearbox can be supplied, if desired. The gearbox with speed-change gears and chain adjusters is readily accessible through large double doors at the front of the base. All clutch locating plungers operate directly on the final driven member, i.e., turret crankshaft, change-speed cam, and bar-feed cam. This obviates clutches sticking from incorrect setting of plungers and ensures that the connecting rod in the turret is accurately aligned after each index.

A very important feature of the turret on this machine is the straight withdrawal and advance mechanism which is built in as standard equipment. This mechanism enables the turret to be rapidly retracted and advanced to the same position without indexing, the turret head remaining positively locked during the operation. By this means, deep holes may be drilled with a single drill and only a minimum of time is lost while the drill is cleared of swarf. The straight withdrawal mechanism may be operated as often as desired and at any point in the machine cycle. Change-over to double indexing is simple, and the additional roller and cam for this purpose are supplied as standard equipment. The front cross-slide is operated direct from its cam by a single lever, whilst the rear cross-slide is actuated by a cam lever, push-rod, and reverse-motion lever at the rear of the machine. By this arrangement inaccessible segments and racks have been eliminated. The single top-slide has micrometer adjustment parallel to the work axis, giving accurate length control; a fine screw adjustment facilitates tool centring for either left-hand or right-hand cutting. By removing two nuts the complete unit can be lifted from the machine. The collet mechanism is also of an improved design. Swinging levers replace the use of collet tube thrust pads to decrease friction and to provide for a greater proportion of the effort applied by the toggle levers being transmitted to the collet.

Another new exhibit from B.S.A. Tools Ltd. was the 8-spindle B.S.A. Acme-Gridley automatic bar machine, model 1⅛ in. BRB. By virtue of its eight spindles, as compared with 4- or 6-spindle automatics, this machine (Fig. 59) is capable of producing two pieces per cycle or, by double indexing, two different pieces per cycle. Furthermore, it permits tooling to include several operations, such as cross-drilling, thread-chasing, and milling, thereby eliminating second operational work. This new machine has a number of interesting features. Thus, for example, maximum accessibility for adjustment and change-over is combined with simplicity of design and rigid construction; the top-slides are set at an angle, providing ready access to tools; and a wide range of spindle speeds is provided, making the machine suitable for a large variety of bar-stock sizes and materials. Other features include power-feed reverse, to save time on set-ups, change-overs, and tool adjustments; rapid indexing; direct thrust of cams to the tool-slide; independent cam control for each slide; a silent stock reel; anti-friction bearings throughout; minimum obstruction to swarf from tools; and four massive cross-slides for heavy forming cuts, with two intermediate side-slides for more versatile tooling.

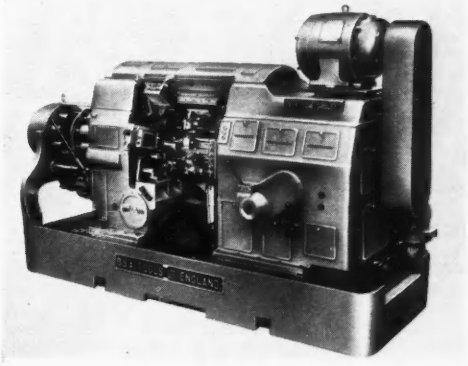
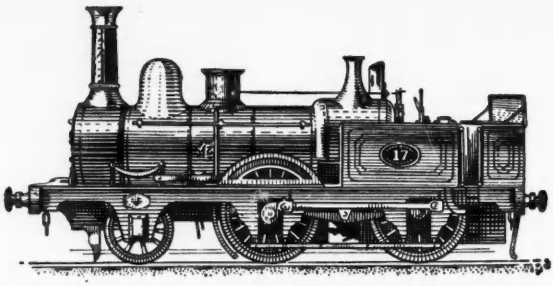


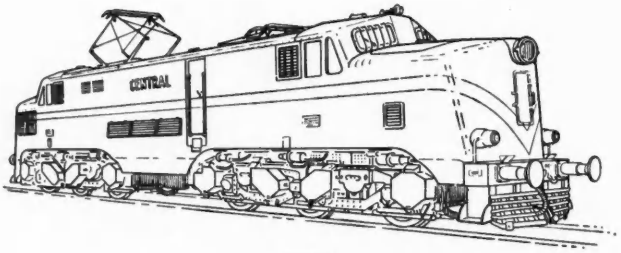
Fig. 59

Other exhibits from B.S.A. Tools Ltd., included the B.S.A. Acme-Gridley 6-in. 6-spindle automatic chucking machine; the B.S.A. vertical broaching machine; the new B.S.A. 95C single-spindle automatic chucking machine; the B.S.A. "48" simplified single-spindle automatic; and the B.S.A. "138L" single-speed automatic screw machine.

Exhibits by **The Sheffield Twist Drill & Steel Co. Ltd.**, of Sheffield, included a comprehensive selection from their range of "Dormer"-brand twist drills, reamers, end mills, screw extractors, etc., together with a range of solid milling cutters and the Dormer A.1 "Supreme"



The span of a century has seen the development from the steam driven tank engine to the electric locomotive. In this period also The Morgan Crucible Company has grown to a unique position, a position in which the products, parts and pieces they develop and manufacture are essential, either directly or indirectly, to every industry throughout the world. Their products may have helped the early designers, certainly today's railway industry recognises the value of their aid—and the future will not ask in vain from the technologists and craftsmen who will use the knowledge and skill accumulated in these past 100 years.



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inserted tooth-milling cutters. These were demonstrated on a modern milling machine, as also were their latest models of "Heli-Cut" and "Heli-Matic" holders for screwed shank tools. The Dormer "Down-Grip" machine vice was also demonstrated, together with their newly developed vice with a fixed jaw.

Among a wide range of equipment, a varied selection of new machines manufactured by George Fischer Limited, of Schaffhausen, Switzerland, was exhibited by **Vaughan Associates Limited**, of London, W.1. Of these, an interesting example is the GF, model KDMS, two-swing copy-turning machine for turbine blades (Fig. 60). Normally, the concave and convex surfaces of turbine blades are machined in two separate operations ; furthermore, the passages between root and aerofoil and between aerofoil and shroud also require separate operations, necessitating the blade to be clamped in various positions by means of special fixtures. With the new GF two-swing copy-turning machine, however, turbine blades can be machined in one operation only, including the passages from aerofoil to root and shroud. This has been achieved by imparting to the tools a non-linear feed ; by causing the feed to rotate about a predetermined axis, virtually perfect cutting conditions from the root to the shroud of the blade are obtained, and machining is effected in one continuous operation, thereby avoiding the overlaps normally produced by separate operations. Moreover, as both the concave and convex surfaces of the blades are machined simultaneously, the cutting forces exerted vertically on the blade profile cancel one another, eliminating the possibility of blade distortion.

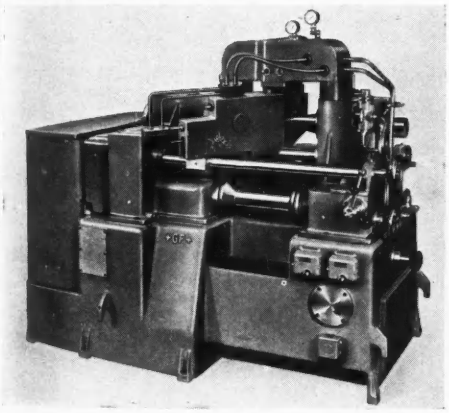


Fig. 60

Other Fischer exhibits by Vaughan Associates include GF copying lathes, model KDM-7/50, equipped respectively with an automatic loader and unloader, model LEV-7, and an automatic bar-feed device, model STA-7. With the automatic loader, attendance by the operator is restricted to the filling of a magazine with blanks and to the removal of the finished workpieces after they have been automatically ejected by the machine, which can accommodate blanks from $\frac{3}{8}$ to $3\frac{1}{8}$ in. in diameter and $2\frac{1}{4}$ to $17\frac{3}{4}$ in. in length. With the automatic bar-feed device, the bar is first machined at the end face and is then clamped between a collet and the centre of the tailstock. The copying slide machines a component and the beginning of the next component, after which a special attachment cuts off the finished workpiece and the tailstock barrel retracts. The bar is then pushed through the spindle until it stops against the tailstock centre, which has now advanced again, the collet closes, and the cycle is repeated.

Another interesting Fischer exhibit by Vaughan Associates is the GF copying lathe for chucking work,

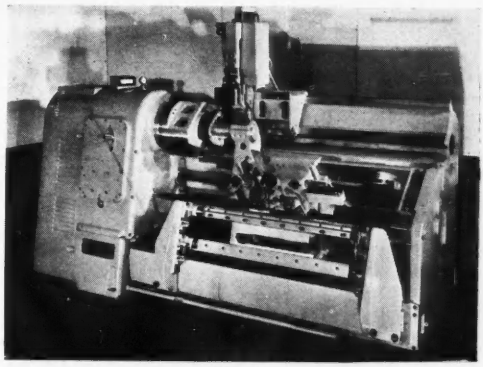
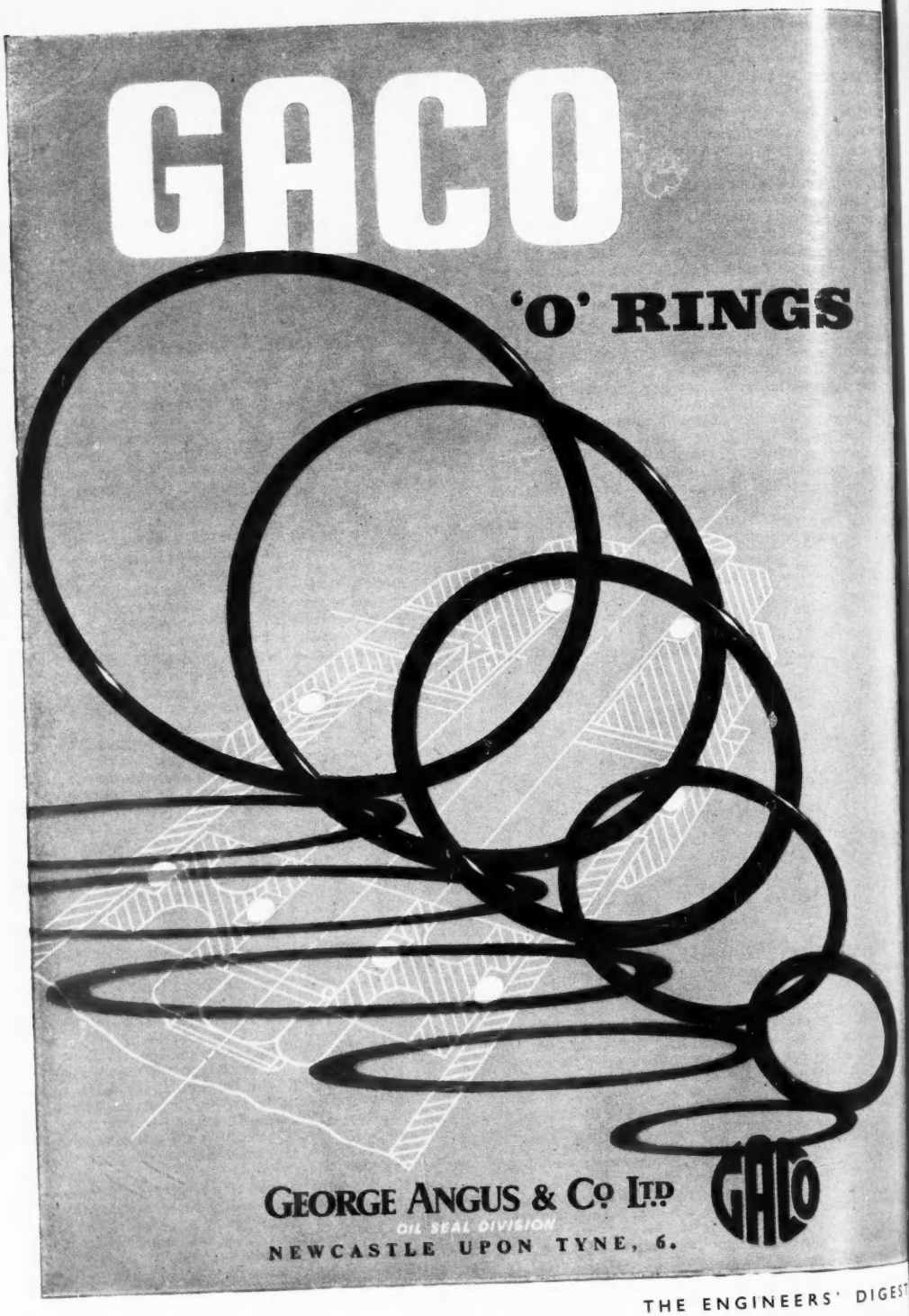


Fig. 61

model KDM-18-28/F. This machine (Fig. 61), which is suitable for small batches or for long runs, and which combines simplicity of operation with versatility and reduced set-up and change-over times, provides automatic programme control, permitting an almost unlimited choice of operating sequences. The tool motions are preselected by means of electrical switches located on a control panel, and sliding dogs mounted on rails are set in accordance with the type and duration of motion required. The sets of rails are fitted to the rear of the feed for the feed carriage, to the copying slide, and to the automatic infeed attachment ; whichever of these is first set in motion automatically starts the other two at the correct points in the cycle. The various motions of the machine can, however, be set up independently by hand by means of appropriate push-buttons—a particularly useful feature when setting up the machine or for small batch-production runs. The automatic spindle-speed change permits work with large differences in diameter to be machined at a nearly constant cutting speed. The headstock gear comprises three spindle-speed groups of six steps each. Within a group, any particular step is switched automatically to any other under load by means of electromagnetic clutches. The entire hydraulic copying system is contained in the copying slide. A hydraulically controlled three-cut recycling device is built into the feed carriage, permitting automatic copy-turning of a workpiece in a cycle of from one to three cuts. Two copying templates, set one in front of the other, swivel automatically into contact with the tracer, this movement being synchronized with the preselected length of cut, and making it possible to work in one operation from two templates with different profiles.

Among the range of equipment exhibited by **H. W. Kearns & Co., Limited**, of Broadheath, near Manchester, was their new optimetric tool-room boring machine, No. 0 series. In this machine (Fig 62), the saddle supporting the main table is carried on a patented main bed of novel design. This bed has a special channel which, in addition to guiding and supporting the centre section of the saddle, houses the bed screw and shaft mechanism. As this section is filled with lubricant, these parts, including the centre-way of the saddle, are submerged in an oil bath. Fabricated sheet-steel covers protect the channel from cuttings and dirt. The ends of the saddle are fitted with large-diameter rollers which ride on the outer ways of the main bed.

On the main table is mounted a revolving table of cellular form, fitted with four hardened-steel inserts which, in conjunction with a hardened-steel locating wedge, enable the revolving table to be set accurately in four positions at 90 deg. At the left-hand end of the main bed are three self-contained units, the 9-speed main gearbox, the feed-box, and a distribution unit. A cushioned drive is provided between the main gearbox and the spindle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slide. A change-gear arrangement in the spindle slide gives a total of 18 speeds to the spindle, these speeds normally ranging between 15 and 750 rpm. The spindle slide is balanced, and the spindle sleeve is mounted on special precision ball and roller bearings. An important feature is the provision of a special nitrided cast-iron bush through which the superfinished nitrided-steel spindle slides in the spindle sleeve. Spindle and sleeve always rotate together as one unit. A new departure in this machine is the use of a spindle feed mechanism which is completely enclosed in a light-alloy casting. This arrangement gives full support to the spindle bearing and at the same time reduces overhung weight to a minimum.

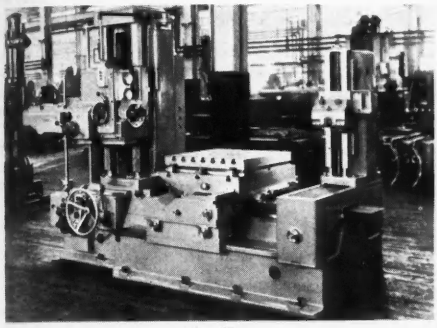

Fig. 62

The patented optical system of coordinate setting on this machine has been developed jointly by Hilger & Watts and by Kearns. The large optical projection screens are fitted to the vertical adjustments of the spindle slide and boring stay, and to the transverse movement of the tables. Setting is to 0.001 in., with an error not exceeding $\pm$ 0·00025 in. As the graduations on the steel rules are projected onto the same side of the screen as the vernier divisions, no parallax errors are possible. Furthermore, all rule mountings are adjustable for zero or the nearest whole-number setting, while the virtually indestructible steel scales are fully protected and are not subject to wear. Other features include a pneumatic time-switch for operating and protecting the optical lamps, and the provision of special independent strips for clamping the spindle slide and boring-stay bearing, thereby avoiding distortion of the slide after setting. In addition, it should be noted that the built-in measuring system requires no end rods, gauges, micrometers, or dials, thus saving time and reducing the possibility of error.

The new machine is capable of boring, milling, drilling, tapping, and screwing operations. As it is supplied with a boring stay with an optical system identical with the spindle-slide unit, line boring operations can easily be carried out. Moreover, the revolving table on which the component is mounted enables all boring, milling, drilling, and tapping operations throughout the 360-deg. rotation of the table to be performed at one setting.

Exhibits from **Kendall & Gent Limited**, of Manchester, included their openside milling machine (Fig. 63), with one vertical milling head on the cross-slide and one horizontal milling head on the upright, each milling head being driven by a 20-hp motor. All traverses are infinitely variable, and the spindles retract automatically on completion of the cut. The table working surface is 4 × 11 ft, the table traverse being 13 ft and the table feeds from 1 to 24 ipm. The maximum height admitted under the vertical face cutter is 4 ft. The milling-head feeds are from 1 to 24 ipm, with a milling-head rapid traverse of 48 ipm. Power feeds to each spindle are between $\frac{1}{4}$ and 6 ipm, rapid traverse to each spindle being 12 ipm. Control is fully automatic.

Also exhibited by Kendall & Gent was a vertical and

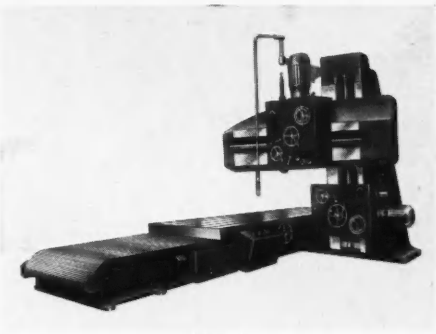

Fig. 63

horizontal plane-milling machine, with all motions independently driven and with one vertical milling head on the cross-slide and two horizontal milling heads, one on each upright. Another exhibit was their duplex horizontal milling machine, with all motions independently driven and with each milling head equipped with a 10-hp drive motor and carrying one vertical and horizontal spindle, the twelve spindle speeds being adjustable from 20 to 320 rpm. This machine has been specially designed for machining all types of rail ends.

In addition to their horizontal broaching machine, size No. 3, with a 60-in. stroke, Kendall & Gent also featured the C.V.M. 60 vertical milling machine, with a 40-hp drive to the spindle and with eighteen spindle speeds between 15 and 840 rpm, and the C.V.M. 25 vertical milling machine. This latter machine (Fig. 64), with a 15-hp drive to the spindle and spindle speeds (18) from 15 to 840 rpm, has a table working surface of 19 in. × 66 in., the longitudinal traverse of the table being 54 in., and the transverse traverse 21 in. Table feeds, infinitely variable by electronic control, range between 8 and 40 ipm, with a table rapid traverse of 120 ipm.

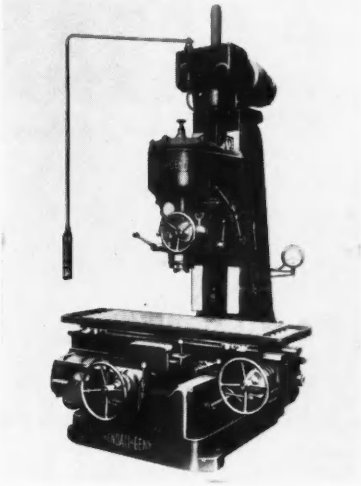

Fig. 64

The "Kenco" range of screwing machines exhibited by Kendall & Gent was represented by a Kenco screwing machine, with a capacity of $\frac{1}{4}$ to 1 in. (tubes or bolts); a Kenco screwing machine, with a capacity of $\frac{1}{2}$ to 3 in. (tubes) and $\frac{1}{2}$ to 2 in. (bolts); and a Kenco screwing machine equipped with a lead-screw feed to the carriage and a taper-threading attachment, the capacity being $\frac{1}{2}$ to 6 in. (tubes), and 1 to 3 in. (bolts).

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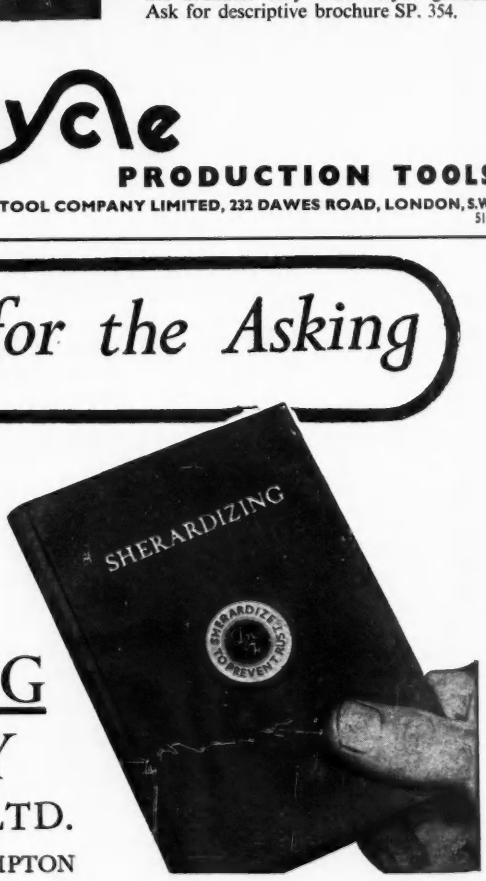

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Designed to meet the need for a machine to give all the advantages of a capstan lathe, while maintaining the essential features of a centre lathe, the new model 5WT capstan lathe, which was exhibited by **Wyvern Machines Limited**, of Leicester, has a swing over the bed of 17 in., a swing over the cross-slide of 9 in., and a swing in the gap of 28 in., the width of the gap from the faceplate being 7 in. The machine can also be used for screwcutting through the quick-change gearbox, without the need for a supply of leaders and nuts. The lead-screw for screwcutting is machined specially accurately, while a split nut, interlocked with the feed motion, engages the screw, and a chasing dial facilitates the cutting of odd and fractional threads.

The turret is arranged with fully automatic feed and is designed to trip at any desired point on each of the six stations. It is also fitted with a coarse and fine feed, in addition to the feeds obtained through the feedbox. Provision is made for mounting an overhead pilot bar, if required. The headstock is of especially robust design, and the main spindle is mounted on opposed taper roller bearings. The pulley transmitting the drive to the spindle is mounted on its own ball bearings, thus relieving the spindle of all belt pull. The feedbox is arranged with 32 changes, controlled by only three levers. An extra lever engages the lead-screw, when required.

Among the machines exhibited by **The Crowthorn Engineering Co. Ltd.**, of Reddish, near Stockport, was a specially designed lathe for the high-speed production of cylinder liners, piston rings, etc., and for the rapid parting-off of ferrous and non-ferrous bar and tube. This machine (Fig. 65) has a number of novel features, including a special parting-off tool-slide assembly, with the operating lever and overhead arm attached to the top of the headstock. In addition, special electrically operated suds equipment is fitted, ensuring a powerful flow of coolant through the bore of the main spindle, while a separate suds pump feeds cutting lubricant to the front and rear tool-holders, which operate simultaneously. Chucking is by means of a specially developed hydraulic chuck. The hydraulic equipment also operates the main driving clutch. A fixture carrying the boring bar is mounted on the saddle adjacent to the two tool-slides, and boring and turning operations are carried out simultaneously, thus achieving a high output. The main drive is from a 7½-hp motor.

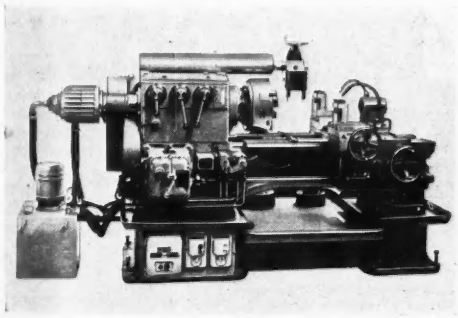

Fig. 65

The largest machine exhibited by Crowthorn was a 36-in. swing boring and facing lathe, which is capable of accommodating a workpiece of 57 in. in diameter in the gap. This powerfully built machine is operated by a 25-hp motor and incorporates rapid power traverse to the carriage, a taper-turning attachment, and numerous other features. Screwcutting gear and a tailstock are optional equipment.

Also exhibited by Crowthorn was a 12½-in. centre (25-in. swing) combination turret lathe. The sturdy hexagon turret is mounted on a power-operated carriage, separate from the 4-way, 8-position hardened-steel tool-post, on an independent power-driven carriage. Rapid traverse to both carriages can be incorporated, if required.

In addition, Crowthorn exhibited their 8¼-in. centre lathe, fitted with a flanged spindle. A special milling and keyway-cutting attachment, a collet chuck, and a micrometer carriage-stop are among the interesting features of this unit.

Typical of the products of the Automation Division of **The Hymatic Engineering Co. Ltd.**, of Redditch, Worcestershire, are two automatic linking devices which were shown on the stands of **B.S.A. Tools Ltd.** and **The Lumsden Machine Co. Ltd.** In each case, the use of equipment powered by compressed air at low pressure shows promise of considerably increasing production.

On the B.S.A. stand, the Hymatic device linked two automatic chucking machines, one with a single spindle, and the other with six spindles. The workpieces—in this case forging blanks approximately 4 in. in diameter and 1 in. in thickness—are loaded by hand into the magazine feed of the single-spindle chucking machine. The Hymatic device feeds the blanks to the first machine and then transfers them to the second. In the first operation, a part-circular clamp with spring-loaded dogs makes contact with the end of the magazine, releasing an escapement so that the next blank to be machined rolls into the clamp. An automatic signal from the machine causes the dogs to tighten on the blank as the loader moves into the axial line of the chuck. A separate axial movement towards the chuck then follows, after which a limit switch signals the chuck to close on the blank, which is immediately released by the clamp. The return of the blank out and up to the magazine feed starts the machining cycle. In this way there is no chance of the machine operating while the loader is in the axial line.

Three of the four turret stations on the chucking machine are used in machining operations. The fourth supports the workpiece while the chuck opens. When the turret turns in the course of the next machining cycle, the previous workpiece is removed and collected by a scoop. It then rolls into position to be picked up by an elevator. As the workpieces roll down they pass through a guide system which turns them over for the next machining process and a zig-zag fall leading to the second machine. The chute acts as a buffer stock. There are limit switches at two points, stopping the first machine and its loader device when the stock is complete. All the pneumatic rams in the loading and linking device are fed with compressed air controlled at 80 psi.

On the stand of the Lumsden Machine Company, the Hymatic device used was designed to remove machined connecting rods from a Lumsden No. 291 LEN 4-wheel surface grinder. Each fixture on the grinding table has two stations and holds two connecting rods. Unground rods are placed on the first station and turned over to the higher station after they are ground on one side. Thus, as each fixture passes under the grinding wheel, one rod is being treated for the first time and the other for the second. The operator loads new rods and turns over those ground on one side, but he has no time to remove the finished workpieces. The installation of the Hymatic device therefore avoids the necessity for a second operator.

The automatic sequence begins when the clamp holding the finished rod in position is released by a cam as the fixture arrives at the unloading station. A striker on the fixture then operates a limit switch, bringing down the arm of the unloader. The continued movement of the table carries the rod web over a flat scoop at the end of the arm, which then lifts the rod away, the movement being exactly timed so that the progress of the table is not impeded. Having lifted the rod through 45 deg., the top section of the arm is deflected upwards by a stop. The rod is then free to fall off the scoop into a chute positioned beside the table. As the scoop actually lies in the path of

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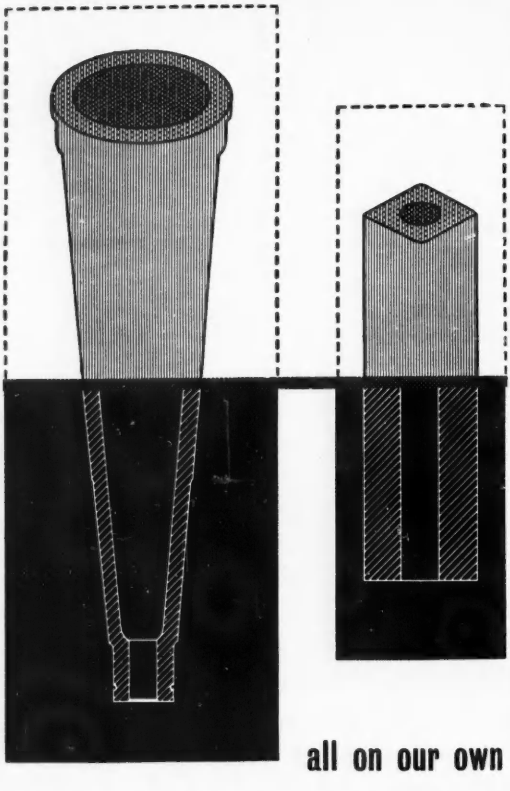

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the fixtures for a short period, a failure in the air or electric supply would have serious consequences. To avoid damage to the machine or the device, the arm is provided with a spring-loaded " elbow " joint connected to a limit switch. Any movement of this safety joint immediately stops the machine table. Compressed-air supply for the unloader is again controlled at 80 psi.

Included in the wide range of equipment exhibited by **Dowding & Doll Ltd.**, of London, W.14, the new Swiss-built Oerlikon D.25 lathe (Fig. 66) is equipped with an interesting arrangement for electro-hydraulic copying. The longitudinal and transverse feeds are infinitely variable and are operated by independent motors and oil pumps—a unique arrangement providing both longitudinal and transverse copying facilities from either flat or round masters. Built-in hydraulic control is also extended to provide power-feed operation of the tailstock quill for drilling and boring operations.

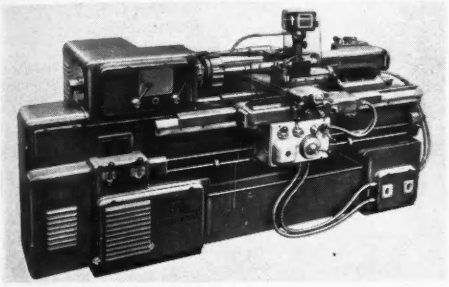

Fig. 66.

Another interesting Dowding & Doll exhibit was the British-built " Rotamill " rotary miller, which has been developed to supplement the well-known smaller " Ahcol " rotary miller. The " Rotamill " is capable of extremely high productivity for milling and slotting operations on a wide range of workpieces, and may be operated with a continuous rotary cycle, or alternatively with an intermittent cycle providing rapid traverse between tooling stations.

The Menziken model M.200 high-speed lathe (Fig. 67), designed and built in Menziken, Switzerland, was also shown by Dowding & Doll and is specially constructed to take advantage of high speeds, the normal top speed of this particular model being 2260 rpm. A relief mechanism of recently improved design is built into the work-head, and, when used in conjunction with the copying device, it permits both profiling and relieving to be carried out on the same machine. Copying templates may be either flat or cylindrical, and, where possible, an actual component can be used as a master.

Other Dowding & Doll exhibits featured a range of Dowding gear hobbers, including vertical universal models of 4 and 8 in. capacity, and a horizontal model with a capacity of 7 in. diameter and 18 in. length ; a

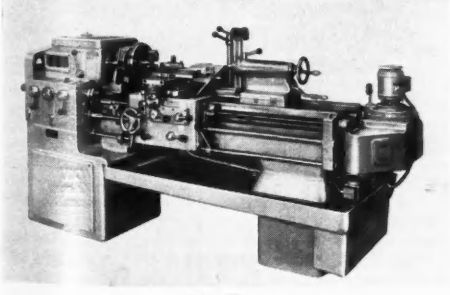

Fig. 67.

range of Wiedemann turret punch presses, now British-built, with capacities ranging from 16,000 to 160,000 lb ; a range of Hare presses, from 5 to 15 tons capacity ; a Lees-Bradner high-production single-spindle gear-hobbing machine, model 7HD—a heavy-duty unit complete with full automation covering loading, unloading, gauging and sizing of components, hob shifting, and automatic depth setting ; a horizontal two-spindle " Rigid " automatic hydro-copying milling machine for turbine-blade profile milling ; a vertical four-spindle fully automatic hydro-copying machine capable of three-dimensional machining of four dies or moulds simultaneously ; and a new version of the " Accuratool " capstan lathe, specially arranged for second-operation work and fitted with a lever-operated tailstock in place of the normal turret.

Among the range of equipment exhibited by **Birlec Limited**, of Erdington, Birmingham, was a complete high-frequency induction installation for hardening localized parts of automobile clutch sleeves. This spline-hardening unit (Fig. 68), which is typical of the specialized installations manufactured by Birlec for particular hardening jobs, was shown in actual operation and is capable of handling from 120 to 150 pieces per hour. With this unit, heating is so rapid that scale formation, grain growth, decarburization, etc. have no time to reach significant proportions, so that final grinding or cleaning operations are eliminated. Furthermore, uniformity of heating and accurate control of heat pattern reduce distortion of the work to an absolute minimum, and there is no heating-up time and stand-by loss, as the heater can be switched on for immediate use whenever it is needed. In addition, the work is processed in a regular flow, thus avoiding wasteful accumulation and transport of batches of material.

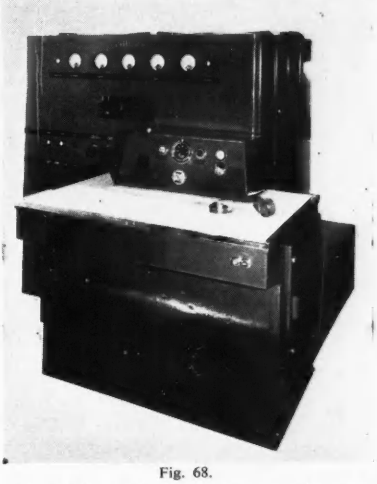

Fig. 68.

Another Birlec unit shown in operation was their recently developed high-frequency vertical hardening unit for general-purpose work. Until recently, induction heating could be applied efficiently only to long continuous runs of selected repetition parts ; now, this new general-purpose machine permits the advantages of the process to be applied to varied batches of work, by providing for rapid and simple interchange of inductors and work fixtures.

Also shown by Birlec was their general-purpose resistance furnace, with a nominal rating of 20 kW and combining uniformity of heating and low heat losses with robust, compact design. Outstanding features of this unit include the totally enclosed, smoothly acting door gear and the durable heat-resistant hearth-plate.

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In the "**Flexmaster**" multi-speed milling machine (Fig. 69), exhibited by **Flexible Drives (Gilmans) Ltd.**, of Smethwick, Staffs., the exceptionally high speed range of from 100 to 24,000 rpm is obtained by using the four-step pulleys fitted to the machine, in conjunction with various geared handpieces, the main speeds of the flexible shaft drive being 1000, 2000, 3000, and 6000 rpm. The ratios provided by the handpieces vary from a step-up of 4 to 1 to a step-down of 10 to 1, according to application, and all handpieces incorporate quick-change fittings. In general, the speed ranges provide for four drilling speeds between 100 and 600 rpm ; four speeds between 1000 and 6000 rpm for brushing, sanding, grinding, or riffling ; three speeds between 5500 and 16,500 rpm for light grinding ; and three speeds between 8000 and 24,000 rpm for profile grinding and for tungsten carbide tools.

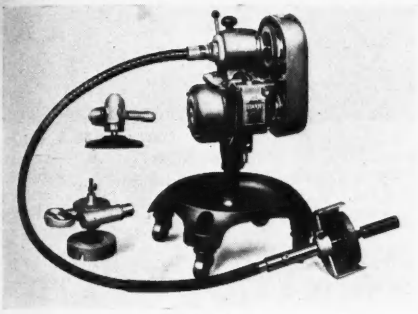

Fig. 69.

The machine is driven from a ¾-hp motor, and a quick-change coupling at the motor end of the flexible shaft reduces the time taken for changing the complete shaft. Two levers at the rear of the machine facilitate belt changing. The flexible drive is rubber-covered and is grease- and acid-proof, and the machine, which weighs about 110 lb, is instantaneously adaptable for floor, bench, or suspended use.

Included among the wide range of equipment exhibited by **Taylor, Taylor & Hobson Ltd.**, of Leicester, was a British-made device which is stated to be revolutionizing methods of aircraft manufacture, ensuring accuracy to thousandths instead of hundredths of an inch, and reducing time and costs by as much as 40%. This device, known as the micro-alignment telescope, provides a comprehensive means of setting up and checking salient points, axes, and planes of any large structure with great precision and speed ; in fact, the old and ponderous methods involving a taut wire level and plumb-bob are now being replaced by this new technique of optical tooling. The equipment successfully copes with work up to 150 ft from the front of the telescope and, in addition to its important uses in aircraft construction, new applications are being found in the setting up or making of guided-missile launching ramps, radar aerials, diesel-engine bearings, marine gearboxes, printing machines, crane bridges, nuclear power reactors, locomotive building and repairing, and all types of machine tools.

In addition to a wide range of cutter grinders, pantograph milling and die-sinking machines, engraving machines, and etchers, Taylor, Taylor & Hobson also featured their "Talyden" workshop microscope, a precision instrument intended for use where accurate measurement is required ; their model 1 "Talyrond" roundness-measuring instrument, for measuring the roundness of parts such as balls and rollers, ball and roller races, pistons and cylinders, fuel injection pumps, and gyroscope components ; their model 3 "Talysurf" surface-measuring instrument, for measuring the roughness of surfaces such as bearings ; their "Talymin" bore comparator, for measuring ball races and bores ; and their turbine-blade edge microscope, which provides a simple device for viewing critically the shape of the leading and trailing edges of turbine blades.

Among a comprehensive range of equipment exhibited by the **Coventry Gauge & Tool Co. Ltd.**, of Coventry, an especially interesting newcomer is their "Matrix" optical diameter-measuring machine (Fig. 70), which is basically of the floating-carriage type originally designed by the National Physical Laboratory and which has been developed in conjunction with Hilger & Watts Ltd. for the accurate and rapid measurement of high-class threaded components. Capable of accommodating work up to 4 in. in diameter, this machine incorporates a high-precision optical unit which enables readings to be taken over a 1-in. range direct to 0·0001 in., without the necessity for resetting.

The machine consists of a sturdy cast-iron base mounting accurately aligned and with adjustable centres. At right angles to the axis of the centres is a freely moving measuring carriage mounted on V-ways and carrying a fixed anvil which is opposed by a movable anvil connected to the optical unit. Measurements along the centre line and at right angles to the component are thus permitted. The optical unit contains a glass scale graduated in divisions of 0·01 in., which are projected at a high magnification onto a ground-glass screen. At the side of the screen is a micrometer which subdivides the optical reading into divisions of 0·0001 in. The large, clearly defined screen enables readings to be taken and repeated without error due to parallax or eye-strain. Furthermore, the system permits two or more operators at a time to view the setting and mutually to agree to the reading obtained. The optical unit incorporates a zero-setting feature which greatly facilitates the initial setting. In order to cover the complete measuring range of the machine, only two reference setting discs, of 1 in. and 3 in. diameter, are required. Compared with other measuring machines, this feature shows a considerable saving in cost. The machine is set to either a 1- or a 3-in. reference disc, according to the diameter of the work to be measured, and readings can be taken over the full scale range of 1 in. without further resetting. The optical unit, being a sliding mechanism, enables repetition checking of work of similar dimensions to be carried out rapidly and accurately.

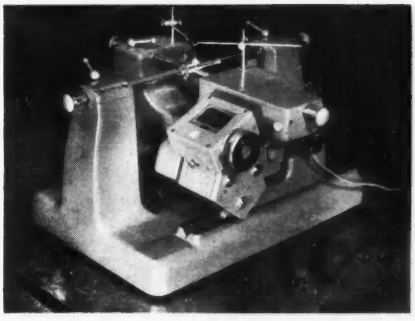

Fig. 70.

Radial measurement can be carried out by locking the floating carriage with a lever provided and bringing the movable anvil into contact with the work, the machine, of course, having been preset in the normal manner to the appropriate reference disc. Odd fluted taps can be easily and quickly measured in this manner. The measuring slide carrying the movable anvil incorporates a spring plunger, and a weight embodied in the casting maintains a constant measuring pressure of 8 oz. A higher working pressure can, however, be obtained easily, if desired. Provision is made for drawing the movable anvil clear of the work and locking it in the non-working position. This enables workpieces to be inserted and withdrawn

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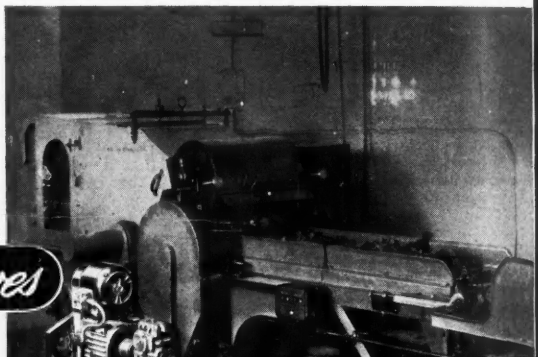

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without disturbing the initial setting. In conjunction with thread-measuring cylinders and prisms, all diametral elements of a thread can be checked. The machine will admit work between centres up to 9 in. in length.

A model is also available for users of the metric system, and in this case the instrument will read directly to 0·002 mm.

A wide variety of equipment has been exhibited by **Thos. W. Ward Ltd.**, of Sheffield and London, and by their subsidiaries, **Fredk. Town & Sons Ltd.**, of Halifax, and **Woodhouse & Mitchell**, of Brighouse, Yorks.

The Thos. W. Ward exhibits included, among other machines, a range of " Eldair " press brakes, guillotines, and shears made by **Weldall & Assembly Ltd.**, of Stourbridge, for which they are world distributors. The 10 ft × ¼ in. hydraulic press brake exhibited (Fig. 71) is an entirely self-contained machine and is powered by a " Towler Electraulic " direct system. Full pressure is available at any position of the stroke, any part of which can be used. Pressure build-up beyond full preset load is prevented by a calibrated pressure switch in the hydraulic circuit, while the ram can be stopped or reversed on any part of the stroke, without disturbing the tool setting, pressure in the cylinders being automatically equalized to prevent tilting of the ram. Single or continuous stroking can be selected, and full pressure is applied at any position of the stroke. The main frame is a rigid steel fabrication, with an extra-deep bed to prevent deflection.

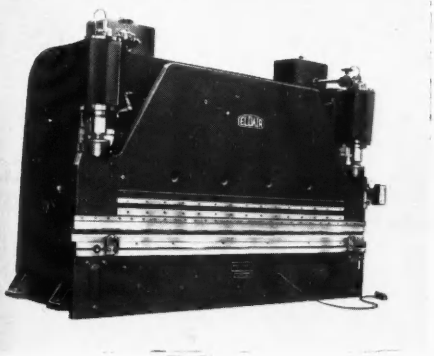

Fig. 71.

Another press brake exhibited by Ward is the 8 ft × ¼ in. mechanical model, with power-operated worm adjustment of the ram. In this machine control may be mechanical or pneumatic, and the use of a multi-plate friction clutch and an automatic brake permit inching of the ram.

The guillotine exhibited by Ward, of 8 ft × ⅜ in. capacity, is designed for high-speed working and continuous operation. The slides are inclined from the vertical for accurate setting and for producing square edges. The alloy-steel blades used, with a section of 4 × 1 in., have four cutting edges to allow for ample regrinds. Other exhibits in this section included two shears. Of these, the No. 1 alligator shear will cut flats up to 24 × ½ in., rounds up to 2 in., squares up to 1⅞ in., angle up to 6 × 3 × ½ in., and pipes up to 6 in. diameter × ¼ in. thick, operating up to 40 strokes per minute. An adjustable rubbing block equalizes the stress on the top beam, and an adjustable knife block facilitates setting of the blades, which have four cutting edges. The whole machine can be mounted on legs or on wheels, as desired. The second shear, designated the " Cub ", occupies only 2 sq ft of floor space and is driven by a 1½-hp motor; however, despite its reduced dimensions, it will shear ¾-in. diameter bar, 6 × ¼ in. flat, or 1½-in. bore gas-piping, at a speed of 40 strokes per minute.

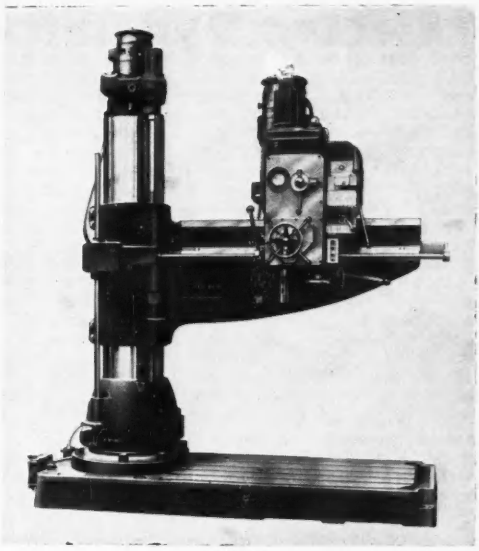

Fig. 72.

The alloy-steel blades used have four cutting edges, and a clutch (hand- or foot-operated) can be fitted, if required.

Also exhibited by Ward were four milling machines from a range made by Riva, of Italy. Of these, three are horizontal, and the other vertical. The largest of the horizontal machines shown was the U.20, with a table surface of 55 × 12 in., a longitudinal traverse of 43 in., a cross traverse of 13¾ in., and an elevation of 18 in. The spindle nose is 2¾ in. in diameter, and 12 spindle speeds, from 12 to 600 rpm, and 24 power feeds, from ⅜ to 18 ipm, are provided, with rapid power traverse in all directions. The vertical milling machine, model V.20, has a head which is inclinable 45 deg. in both directions from the vertical. The table has a working surface of 55 × 14 in., an automatic longitudinal traverse of 43 in., a cross traverse of 16 in., and an elevation of 17¾ in.

The exhibits by Fredk. Town & Sons Ltd, comprised a wide range of drilling machines, including several redesigned types. Thus, for instance, the 6-ft heavy-type C.E.2 radial drilling, boring, tapping, and studding machine (Fig. 72) has a new saddle, with all controls concentrated within easy reach of the operator. Provision is made for 18 spindle speeds, ranging from 15 to 850 rpm, direct-reading speed plates showing the correct speeds and feeds for different diameters of drill when drilling mild steel and cast iron. Power feed is easily engaged and disengaged, 8 rates of power feed being provided, ranging from 0·020 to 0·004 in. per revolution. The drive is via a 7½-hp constant-speed motor through a multi-plate friction clutch, a separate 3-hp motor, operated from the saddle, being used for elevating and lowering the arm. This machine will drill up to 3 in. from the solid in mild steel, or 3½ in. in cast iron, and will tap up to 2 in. Whitworth in mild steel.

Other Town exhibits included their A.E.4 radial drilling, boring, tapping, and studding machine, shown in two sizes, i.e., 6-ft radius and 4-ft radius; their 6-ft girder radial drilling machine, with four speeds and three feeds; and their 30-in. model A.E.4 vertical drilling, boring, tapping, and studding machine—a medium-capacity unit for drilling up to 2½ in. from the solid in mild steel.

Exhibits by Woodhouse & Mitchell featured a range of lathes, including surfacing and screwcutting lathes and centre lathes; a model of a new horizontal boring, facing, and milling machine, now in course of production; and a new turret milling and slotting machine.

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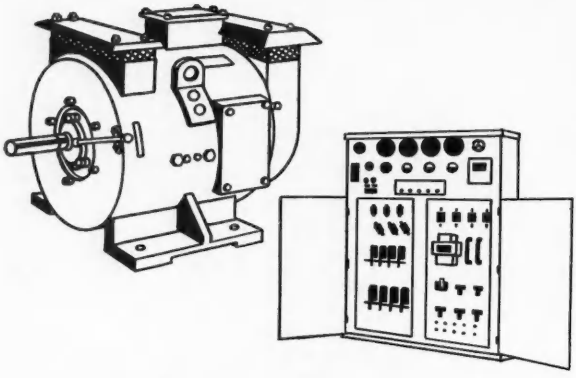

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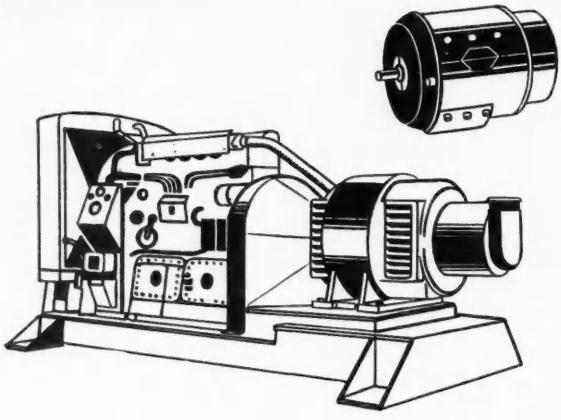

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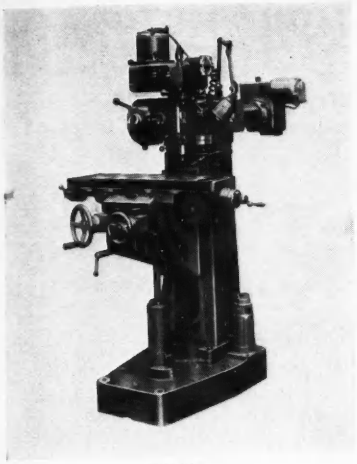

Fig. 73.

The turret milling machine (Fig. 73), which is of entirely new design, has a 15-in. diameter turret, with the spigot located in the column and graduated to rotate through 360 deg. The overarm, which slides through the turret, can be angularly set in one plane by turning a worm and wheel, the rotating motion of the head and the sliding motion of the arm being locked by pad bolts. When required, a slotting attachment can be fitted at the opposite end of the arm from the milling head. The spindle and quill of the milling head are of alloy steel, flame-hardened and ground, the quill housing being honed. The spindle is mounted on roller bearings. Rapid hand feed is provided to the spindle, and this can be disengaged, bringing into operation the fine feed, which can be advanced or retarded through a graduated dial. A micrometer depth-stop bar is fitted. The driving-pulley housing can be swivelled completely round the spindle to facilitate the use of the head at any angle. The head can be rotated through 360 deg. in the vertical plane and locked in any position. Special attention has been paid to the design of the column and base to give rigidity and ample bearing surface to the knee, which has adjustable-taper wear strips. Graduated dials are fitted, and controls and clamps are placed on the front of the machine. The cross-slide and table have long bearing surfaces with adjustable-taper wear strips.

Exhibits by **F. J. Edwards Limited,** of London, N.W.1, included an entirely new machine, the " Besco " production motorized swing-beam box and pan press brake, model 36/10 (Fig. 74), a feature of which is that the top beam is arranged to swing out, thus enabling trunk sections which have been formed around the beam to be withdrawn complete. Another feature is that pan, box, and tray work may be preformed by means of the segmental blade supplied ; this blade, which can be easily and quickly attached when the ordinary angle bending blade is removed, consists of detachable fingers which can be assembled at any point along the beam, enabling boxes to be formed to a maximum depth of 6 in. These fingers are of various widths, making up the maximum bending length of 36 in.

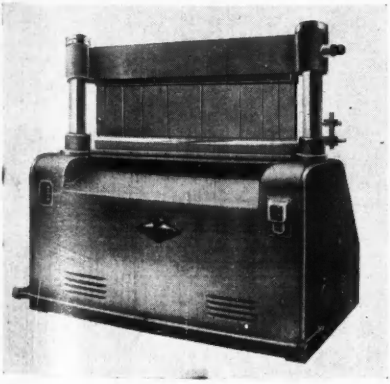

Fig. 74.

The top beam, machined from steel plate, swings out in double thrust bearings and is locked in the operating position by a spring plunger. Adjustment up to 8 in. high is effected by a side handle, so that blades of various heights can be accommodated, either for production angle bending or for open-topped boxes or trays. The minimum size of a trunk section formed is $8\frac{1}{2} \times 8\frac{1}{2}$ in. The length of the stroke is 1 in. With the stroke up, the maximum distance of the ram to the bed is 12 in., and the minimum 4 in.

Among a wide range of pneumatic tools which were exhibited by **Desoutter Brothers Limited,** of Hendon, London, N.W.9, an item of special interest was their pneumatic " Rackfeed " drills, which have been designed to simplify the drilling and reaming of holes up to 1 in. in diameter, enabling the work to be carried out by unskilled operators. The main features of the tool are a geared hand feed and a bayonet-nose jig fitting. The geared hand feed permits a load of 250 lb to be applied with only finger-tip pressure, so that fatigue is eliminated and the depth of penetration can be accurately controlled by means of an adjustable depth-stop on the rack. The bayonet-nose fitting ensures correct alignment and absorbs drilling reaction.

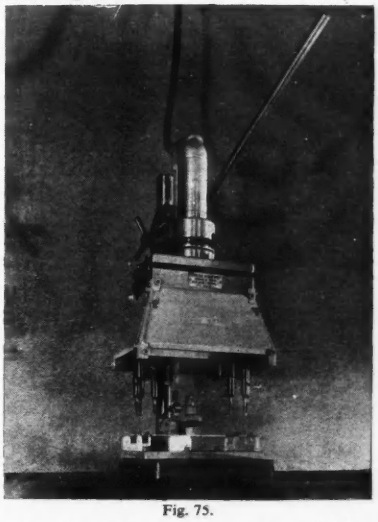

Fig. 75.

Another Desoutter exhibit was a multiple-spindle tapping machine (Fig. 75), designed to tap up to 8 holes of 4 BA simultaneously. The pattern of the tap spindles can be varied to suit the holes in the job, from $\frac{1}{2}$-in. centres up to the maximum area of the spindle plate (7×5 in.). The machine can be arranged to tap holes varying in size from 2 to 6 BA at one time. When tapping 2 BA only, the maximum number of spindles which can be brought into use is six. The motive power is a standard Dessouter R16/25S pneumatic tapper. The complete machine was designed and produced by the Gildersleve Design and Tools Company, of Reigate, Surrey.

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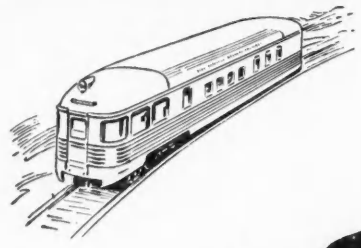

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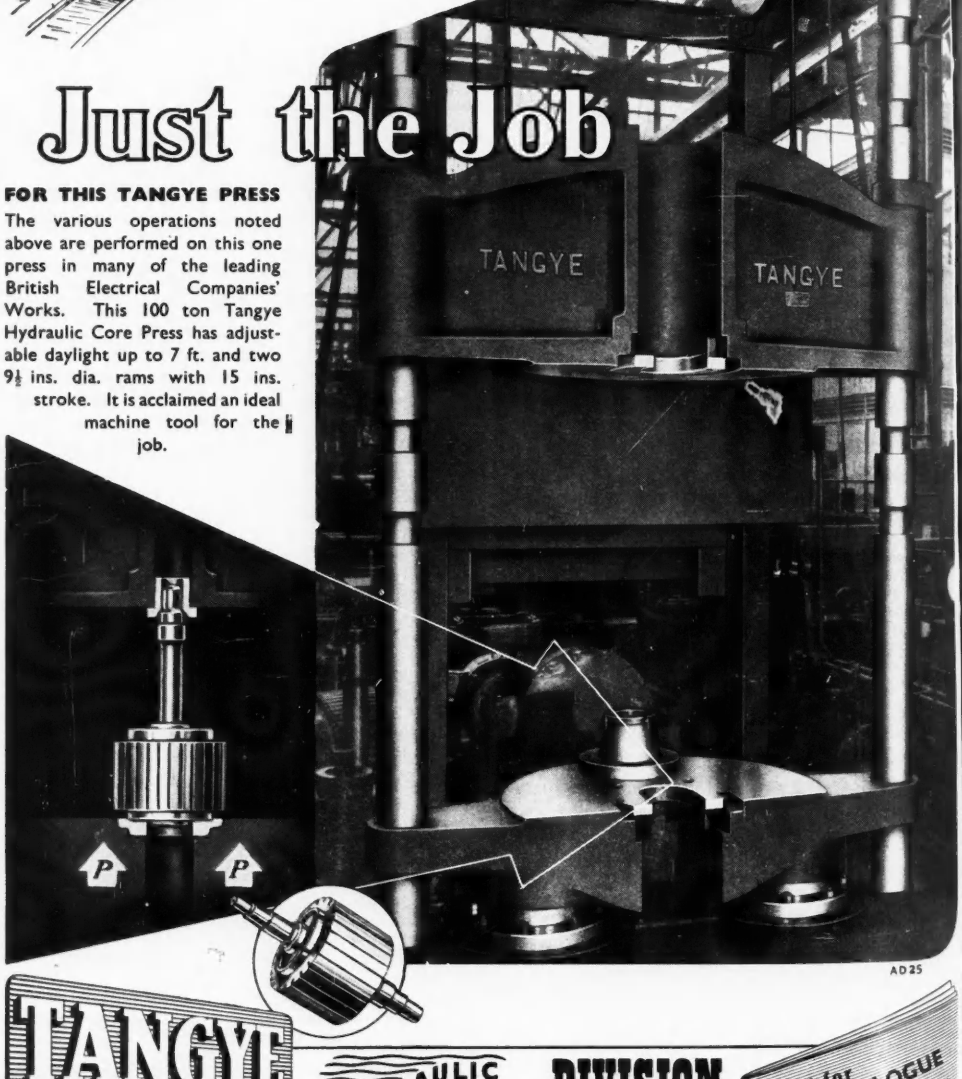

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NEWS OF THE MONTH

PERSONAL

Mr. H. F. Adams, has been appointed director of manufacture, **Mr. D. H. Graham,** director of design, and **Mr. D. T. L. Rettie,** director of marketing, of the Hotpoint Electric Appliance Co. Ltd., Peterborough.

Mr. John S. V. Andrews has been appointed chief planning engineer of James A. Jobling & Co. Ltd., Sunderland.

Mr. R. Askin has been elected to the Board of J. Brockhouse & Co. Ltd., Victoria Works, West Bromwich.

Mr. S. J. Beaney has been elected a director of Barbados Electric Supply Corporation Ltd., Suffolk House, Laurence Pountney Hill, London E.C.4.

Mr. G. W. Burger has been appointed managing director of Knowsley Cast Metal Co. Ltd., Titan Works, Trafford Park, Manchester 17.

Mr. Brian Cape, A.I.E.E., has been appointed technical services manager to Kelvin & Hughes (Aviation) Ltd., Basingstoke, in succession to **Mr. John Rivaz,** who recently joined Smiths Aircraft Instruments Ltd.

Mr. L. Childs has been appointed manager of Blast Furnace and Coke Oven operations of Ford Motor Company Ltd., Dagenham, in succession to **Mr. F. Pearson,** who relinquished his position, but will continue for a period to assist in the developments relating to the company's Blast Furnace and Coke Oven facilities.

Mr. Hugh F. Colvin has been elected President of Consolidated Electrodynamics Corporation, 300 North Sierra Madre Villa, Pasadena, California, to succeed **Mr. Philip S. Fog,** who will continue as chief executive officer and will remain in control of general company policy.

Mr. Lester Combe has been appointed factory manager of the Reconnaissance Systems Division of Fairchild Camera and Instrument Corporation, Robbins Lane, Syosset, L.I., New York, U.S.A.

Mr. V. J. Cooper, M.I.E.E., has been appointed chief television engineer, and **Mr. G. E. Partington, A.M.I.E.E.,** deputy chief television engineer of Marconi's Wireless Telegraph Co. Ltd., Chelmsford. **Mr. E. Davies, Mr. M. N. Parker-Smith, Mr. J. E. Nixon,** and **Mr. S. J. Gooderham** have been appointed to take charge of three recently formed television development groups and an audio development group.

Mr. E. Crossley has been appointed managing engineer, and **Mr. J. N. Buchanan,** principal surveyor, of the separate Land Division of Lloyd's Register of Shipping, which has been formed in view of the expansion of non-marine work of the company. **Mr. G. Auterson** has been appointed principal electrical engineer surveyor, in succession to **Mr. G. O. Watson,** who has retired, but will continue to serve as a consultant. **Mr W. Macmillan** has been appointed principal surveyor in charge of the Freeboard Department. **Mr. A. T. Sheffer,** senior ship surveyor for Germany, has been promoted to principal surveyor.

Professor M. W. Humphrey Davies has been appointed to the Chair of Electrical Engineering at Queen Mary College of The University of London. **Mr. P. T. Fink** has been appointed to the readership in Aeronautics, and **Dr. W. L. Wilcock** to the readership in Instrument Technology, at the Imperial College of Science and Technology.

Mr. Ralph H. Dean and **Mr. William G. Corless** have been elected to the Board of Parmiter, Hope & Sugden Ltd., Fluvent Electrical Works, Longsight, Manchester 12.

Mr. H. A. Denne, O.B.E., general export manager, and **Mr. F. E. W. Hammond,** purchase manager, have joined the Board of Ford Motor Co. Ltd., Dagenham, Essex, and have been appointed executive directors.

Mr. P. W. Gamble has been elected a director of Boulton & Paul Ltd., Norwich.

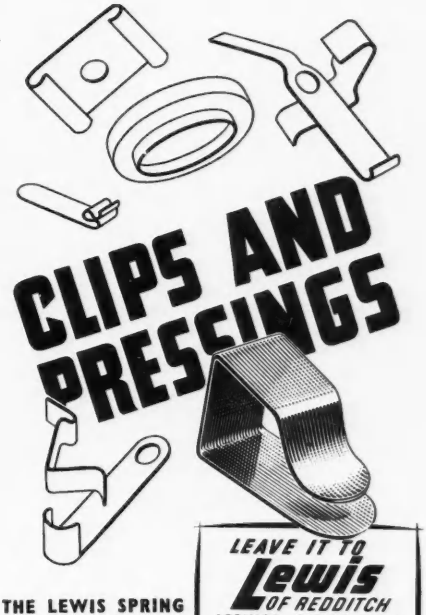
Mr. Robert Gillespie has been appointed managing director of the British Petroleum Co. Ltd., Brittanic House, Finsbury Circus, London E.C.2.

Mr. H. N. Hacking has been appointed works manager of Clifford Aero and Auto Ltd., Birmingham.

Mr. E. W. Hancock, M.B.E., M.I.Mech.E., Hon.M.I.Prod.E., F.I.I.A., F.R.S.A., director and general manager of Humber Ltd., has been elected President of the Institution of Production Engineers. **Mr. H. G. Gregory, M.I.Prod.E.,** manager of the Northern factories of Fairey Aviation Ltd., has been elected chairman of the Institution.

Mr. W. A. Hawkins, senior associate editor of *Metalworking Production,* has resigned and has taken up the position of sales manager with Vaughan Associates Ltd., 4 Queen Street, Curzon Street, London W.1.

Mr. A. H. Hird, A.C.G.I., M.I.Mech.E., has been appointed a special director and adviser on group commercial engineering sales for Vickers Ltd., Vickers House, Broadway, London S.W.1. He has also been elected chairman of A.B.C. Motors Ltd., Cooke,



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ES/T29

Troughton & Simms Ltd. and Ioco Ltd. **Rear-Admiral Sir Anthony Buzzard, Bt.,** has been appointed a special director of Vickers-Armstrongs Ltd. and assistant to the managing director. **Mr. R. Wonfor** has been appointed sales director and **Mr. J. E. Richardson** has been appointed a director of Vickers-Armstrongs (Engineers) Ltd.

Mr. S. R. Howes, M.I.Prod.E., has retired as director and general manager of Samuel Fox & Co. Ltd., and has been elected a director of The United Steel Companies Ltd., 17 Westbourne Road, Sheffield 10. He has agreed to serve for a further three years as consultant for work study and operational research for all steel-making branches of United Steel.

Mr. J. R. Hudson has been appointed joint managing director of The Moss Gear Co. Ltd., Tyburn, Birmingham. **Mr. A. W. Macferson** has been appointed to the Board.

Mr. H. W. H. Icough, manager of the wirework and wire weaving departments of G. A. Harvey & Co. (London) Ltd., Greenwich Metal Works, London, S.E.7, has retired from the service of the company. Mr. Icough, an authority on the weaving of wire, was chairman of the Executive Committee of the Woven Wire Manufacturers' Association continuously for the past fourteen years.

Mr. William Jobling, technical manager of William Doxford & Sons (Shipbuilders) Ltd., has been elected to the Board. **Mr. James A. Hardy,** technical manager, and **Mr. Percy Jackson,** manager of the research deveiment department of William Doxford & Sons (Engineers) Ltd., have been elected to the Board of that company.

Dr. J. M. Kay has been appointed to the newly created Chair of Nuclear Power at the Imperial College of Science and Technology.

Mr. Clifford Metcalfe has been appointed managing director of E.M.I. Electronics Ltd., a subsidiary company of Electric and Musical Industries Ltd.

Sir Steuart Mitchell, K.B.E., C.B., M.I.Mech.E., Controller, Guided Weapons and Electronics, has been appointed to be Controller, Royal Ordnance Factories, and also Head of the Ministry of Supply engineering staff. **Mr. A. T. Barnard, C.B., O.B.E., A.M.I.C.E.,** has been appointed to be Director-General of Inspection, and **Mr. R. Ratcliffe, M.B.E., M.I.Mech.E.,** has been appointed to be Director-General of Ordnance Factories.

Mr. A. W. Page has been appointed sales manager of the Igranic Electric Co. Ltd., Bedford. **Mr. E. G. Harrison** has been appointed London manager and will continue as the company's export manager at Victoria Station House, Victoria Street, London S.W.1.

Mr. A. E. Saunders, F.C.W.A., F.A.C.C.A., has been appointed to the new position of director and comptroller, and **Mr. R. F. Beioley, A.S.A.A.,** has been appointed secretary of Webster & Bennett Ltd., Coventry.

Mr. Harold Saunders has been appointed manager of the constructional engineering department of Thos. Storey (Engineers) Ltd., Stockport.

Mr. C. F. Uwins, director of Bristol Aeroplane Co. Ltd., has been elected President, and **Mr. A. F. Burke,** managing director of de Havilland Aircraft Co. Ltd., has been elected vice-president of The Society of British Aircraft Constructors Ltd. **Mr. J. J. Parker** has been elected deputy president, and **Sir Frederick Handley Page** has been re-elected honorary treasurer.

Mr. W. Eric Ward, general works manager responsible for all iron and steel production of the Consett Iron Co. Ltd., has been appointed a local director.

Mr. Roger D. Wellington, B.S.M.E., M.B.A., has been appointed assistant to **Mr. J. L. Thompson,** general manager of Square D Ltd., 100 Aldersgate Street, London E.C.1.

Mr. G. W. Wood, assistant managing director of A. E. Jenks & Cattell Ltd., Wednesfield, has been appointed chairman and managing director of the company, in succession to the late **Mr. G. B. Jenks.**

Sir Richard Yeabsley, C.B.E., F.C.A., F.S.A.A., has been elected deputy chairman of F. Perkins Ltd., Peterborough. **Mr. M. I. Prichard,** director in charge of engineering since 1954, has been appointed deputy managing director.

BISRA "OPEN DAYS" AT SHEFFIELD LABORATORIES

The British Iron and Steel Research Association will hold two "Open Days" at the Sheffield Laboratories on Thursday and Friday, 6th and 7th September, 1956, for representatives of member firms.

Primarily, the "Open Days" will provide the opportunity for demonstrating the progress which has been made by those Divisions of BISRA housed at Sheffield—Mechanical Working, Steelmaking, and Metallurgy (General)—since the premises were opened in November, 1953 by H.R.H. The Duke of Edinburgh, K.G.

The Mechanical Working Division, for example, will be mounting a series of displays relating to wire-drawing (including high-pressure lubrication), work on forging problems, developments in hot and cold rolling, and studies of sheet metal working characteristics. Steelmaking Division will show various aspects of research into electric-arc furnace operation and economics, advances in ingot feeder-head design, and progress in the immersion-casting technique for steel strip. Open-hearth furnace instrumentation will be demonstrated by displays including the BISRA scale model open-hearth furnace equipped with a calorimeter hearth and apparatus necessary for the study of flame characteristics and convective heat transfer. The Division's Process Chemistry Section will display the vertical high-temperature globar furnace used in the investigation of sulphur

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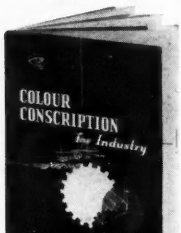

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Perspective drawings can be supplied for your guidance in following these principles ; you are invited to make full use of this service.

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pick-up by melting steel from the impingement of oil droplets. Other aspects of the Division's work will be included in the display.

Metallurgy (General) displays relating to electrical sheet research will include work on the effect of impurities on the magnetic properties of silicon-iron, and studies of strain-ageing alpha iron. Also on show will be exhibits illustrating investigations into grain-boundary properties and their relation to internal friction, and studies of static hysteresis curves for soft ferro-magnetic material. An extensive display of advanced methods of analysis will also be mounted, including micro-chemical, absorptiometric, spectrographic, and vacuum fusion methods.

The many static displays will be reinforced by a series of working demonstrations—notably of such developments as the continuous casting of steel, and the use of automatic gauge control on the 14-in. experimental rolling mill.

While the main emphasis will understandably be concentrated on the work of the Mechanical Working, Steelmaking, and Metallurgy Divisions, those other sections of BISRA located in London, Swansea, and Normanby will also be represented by minor displays. The various services developed by the Association over recent years will also be illustrated, and the associated research organizations housed at Sheffield—the Cutlery Research Council, the File Research Council, and the Coil Spring Federation Research Organization—will also be represented.

The laboratories will be open from 10 a.m. to 5 p.m. and luncheon and afternoon tea will be provided for visitors. Invitation cards and further details will be issued in the near future.

" THE FERODO STORY "

Originally produced by Ferodo Limited to assist their overseas agents in presenting the facts about Ferodo products to the motor industry and motoring public, this film tells the story of the development of brakes and clutch linings through over fifty years of progress in automobile engineering. Before the turn of the century, Herbert Frood, the founder of the firm, became interested in the primitive types of brake linings used by carters in the hilly Peak District of Derbyshire, and he concluded that something more efficient than the old boot usually employed to supplement a worn wooden brake-block might well be found. Tracing his successful early experiments with chemically impregnated asbestos fabric as a brake-lining material," The Ferodo Story " depicts some of the processes necessary to the production of modern friction materials, including formulation, impregnation, moulding, curing, shaping, cutting, grinding, gauging, and testing—a range of intricate, yet essential, operations which might well seem incredible to those who are accustomed to regard a brake-lining as a simple, everyday thing.

In its running time of twenty-four minutes, this competently produced and photographed film can hardly be expected to show all Ferodo products and their applications. Even so, it successfully touches on a considerable number, ranging from small brake-blocks for cycles to special brake-linings for motorcycles, automobiles, aircraft, locomotives, mining equipment, earth-moving machinery, and agricultural equipment, to clutch linings of many types and sizes, fan-belts, and even non-slip stair-treads. It is not surprising, therefore, that today the Ferodo factory is the largest single unit in the world producing friction materials. It must also be, as is well brought out in the film, one of the most beautifully sited factories in the world, set as it is in the ancient and delightful little town of Chapel-en-le-Frith in the hills of Derbyshire.

" The Ferodo Story " is in no sense a technical film; rather, it has been produced for " prestige " purposes and here it succeeds admirably, for, by combining the best features of a documentary and a travelogue, not only does it enhance the prestige of the Ferodo company but also the loveliness of the English countryside.

The film (16 or 35 mm, sound) was produced in Eastman colour by Screen Audiences Limited (part of the J. Arthur Rank Organization) and is available with sound-tracks in English and Spanish. It may be borrowed for screening at trade gatherings, technical conventions, car-club meetings, etc., on application to the Public Relations Officer, Ferodo Limited, Chapel-en-le-Frith, Stockport.

MIXED-POWERPLANT FIGHTERS

Mach-2 fighter aircraft climbing vertically at 350 mph, powered by turbojet and rocket engines, armed with missiles which " lock on " to enemy bombers at a range of several miles: that is tomorrow's pattern of outer air defence which will be supplemented by ground-launched guided weapons over home territory.

The British Aircraft Industry is actively engaged on developing aircraft and engines to fill these requirements and, although security prevents the publication of details, a certain amount of information has been released. Avro and Saunders-Roe are at present building mixed powerplant fighters, the *720* and *S.R.53*. The make and type of engines to be used are secret. A number of engine manufacturers are engaged on rocket-engine development, one of the first to be announced being the Armstrong Siddeley *Snarler*. The same company make the *Screamer*, while de Havilland are soon to start flight trials with the *Spectre*.

WHAT WE DO IS OUR CUSTOMERS' SECRET...It must not be talked about...which is all very trying because we would like to give you some idea of the size, character and variety of JIGS and SPECIAL PURPOSE MACHINES we are producing--some are really ingenious. We can tell you though, that we are consulted and employed by many of the foremost Engineering concerns in the Country. Why not discuss your next problem with us? WM. C. FRANCIS LTD., Canley, COVENTRY. Mfs. also of Precision Tools, Prototypes & Welded Constructions. A.I.D. Approved.

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The need for the mixed-powerplant fighter has been brought about by the formidable performance of modern bombers. Today, high sub-sonic speeds at above 50,000 ft are commonplace and soon speeds of 900 mph, or more, in the stratosphere can be expected. Such a bomber would approach its target at 15 miles a minute, thus making fighter aircraft that can reach, perhaps, 60,000 to 70,000 ft in a very few minutes, a vital necessity.

The turbojet engine loses power at altitude. An engine which gives 20,000 lb thrust at sea level will develop only 3500 lb at 60,000 ft and has a practical limit of 70,000 ft. A rocket-engine, on the other hand, operates independently of the surrounding atmosphere as it carries its own oxidant. But its fuel consumption is heavy. A typical rocket motor would consume about 50 tons of fuel an hour if run at full throttle—an unlikely event. Fuel weight is compensated to a certain extent by very low engine weight. The *Snarler* weighed only 215 lb for its thrust of 2000 lb.

There are two approaches to designing mixed-power-plant fighters. One, typified by the French *Trident*, advocates the use of rocket engines as the main power units with a relatively small turbojet for cruising. The other school of thought, with de Havilland as its sponsor, maintains that a large turbojet engine should provide most of the power, using rocket-engines as boosters. This manufacturer has published a flight plan for an interceptor powered by a *Gyron* and two *Spectres*. For take-off and initial climb, a *Gyron* with reheat is used, to be augmented by *Spectres* to maintain the rate of climb at high altitudes and to accelerate prior to " locking on " to the target. A *Gyron* with reheat is used when approaching the target, augmented by rocket power for manoeuvring in combat. For return to base, turbojet without reheat is used.

A variety of missiles to destroy bomber aircraft is also being evolved in this country. Recently, the *Fireflash* was announced, a weapon which, once the fighter has " locked on " its target by radar, is released and which is self-detonating by means of a proximity fuse. The *Fireflash* is to be delivered to the R.A.F. during the current financial year and is also available for export.

A development of this weapon is the longer range " homing " missile, which transmits impulses, the reflection of which are picked up again and used to direct the missile's path. It follows that a transmitter as well as a receiver must be carried and, at present anyway, it seems likely that only larger guided weapons will be so equipped.

The use of infra-red rays as a " homing " medium is also under development. The parent aircraft need not carry guidance equipment as the missile itself " locks on " to the bomber's jet efflux regardless of the latter's evasive action. This, however, may take time to perfect for operational use.

BUSINESS NOTES

The first **Instruments, Electronics and Automation Exhibition** covering the complete field of laboratory and industrial instrumentation and the evergrowing uses of electronics will be staged at Olympia, London, from 7th to 17th May, 1957. The exhibition is being promoted by the British Electrical and Allied Manufacturers' Association; the British Industrial Measuring and Control Apparatus Manufacturers' Association; the British Lampblown Scientific Glassware Manufacturers' Association; the Drawing Office Materials Manufacturers' and Dealers' Association and the Scientific Instrument Manufacturers' Association of Great Britain.

It is being arranged on their behalf by a newly formed exhibition organization—Industrial Exhibitions Ltd., 105-106 New Bond Street, London W.1, headed by Mr. T. E. Rees, until recently deputy to Kenneth Horne, managing director of British Industries Fair Ltd.

An intensive advertising drive is being planned for the exhibition.

Complementary to the exhibition will be a continuous programme of conferences, lectures and meetings, which will provide the opportunity for full discussion and consideration of the many and varied problems arising from the rapidly changing pattern of industrial development and the use of new techniques in industry.

The instrument industry is in the forefront of progress since most new scientific and technological achievements are only made possible by the development of new instruments and over new techniques.

A Fuel Efficiency Exhibition will be held for the first time at Olympia, London, from 2nd to 10th October.

It will have as its theme " Clean the Air ". The latest plant and equipment, designed to reduce " smog " and fuel bills, will be featured.

The exhibition will be under the auspices of the National Industrial Fuel Efficiency Service (a government-sponsored body) and the Combustion Engineering Association, and will be organized by Provincial Exhibitions Ltd. This exhibition has been staged in recent years in Manchester, but has proved of such wide interest that it is being moved to London in order to provide increased space and facilities.

Over 100 leading firms have already taken space, including the Atomic Energy Authority. Developments in instrumentation and electronics will appear on many stands.

With rising costs of fuel a need for greater efficiency is becoming more vital. Economic heating and smokeless zones are matters of concern, not only to large and small factories, but to hotels, flats, and even domestic householders. Many thousands of trade visitors will be attracted from all parts of Britain and from overseas.

The British Aircraft Industry's export total for May is the second highest ever recorded. At £8,338,536 it ranks second only to the March figure and brings the total for the first five months of 1956 to £45,439,648, which is 77% more than was achieved in the same period last year when a record annual total of £66,189,978 was recorded.

The figure for the first five months exceeds the annual export totals of all previous years with the exception of 1953-5 inclusive.

During May, the United States was yet again Britain's best customer with £1,821,958 worth; France (£453,906), Canada (£363,814), and Australia (£320,331) came next.

The First Private Nuclear Reactor in the United States went into operation in Chicago on 28th June. The 50,000-watt reactor is operated by the Armour Research Foundation of Illinois Institute of Technology and supplies twenty-four industrial concerns. It will be used mainly for the production of radio-isotopes and the study of chemicals and other materials.

The Dunlop Rubber Co. Ltd., announce that permission has now been received for the erection of a £5,000,000 synthetic rubber plant at Fawley, Southampton, by the International Synthetic Rubber Co. Ltd.

The project has been undertaken by a group headed by the Dunlop Rubber Co. Ltd., with whom the Goodyear Tyre and Rubber Co. Ltd., the Firestone Tyre and Rubber Co. Ltd. and the Michelin Tyre Co. Ltd. are associated.

The plant is being designed and planned by the Chemical Plants Division of the Blaw-Knox Corporation, Pittsburgh, but the construction work will be carried out by British contractors, and the bulk of the machinery will be of British manufacture.

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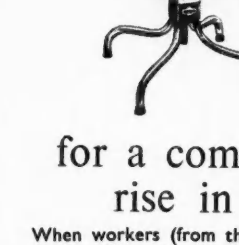

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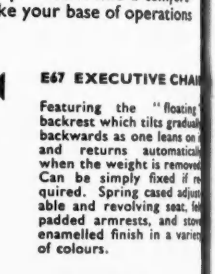

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It is estimated that in about two years the plant will be producing 50,000 tons of synthetic rubber a year, resulting in a saving of 30,000,000 dollars.

Darwins Limited, Tinsley, Sheffield 9, announce that their subsidiary company, J. Stead & Co. Ltd., have acquired the screwdriver manufacturing division of Endo Industries Ltd., Redditch.

The Sunderland Shipbuilding Dry Docks and Engineering Co. Ltd. announce that they have acquired control of the Wear Winch and Foundry Co. Ltd., Commercial Road, Sunderland, which concern has now become part of the Group.

Rubert & Co. Ltd., Levenshulme, Manchester 19, have been appointed sole agents for Great Britain for the Test Indicator Stands and Granite Surface Plates manufactured by Hommelwerke G.m.b.H., Mannheim-Kaefertal, Germany.

The Cape Asbestos Co. Ltd., 114-116 Park Street, London W.1, announce that their Midland area office has moved to new premises at 11 Waterloo Street, Birmingham 2. Tel. No.: MIDland 6565. Mr. F. M. G. Coupe is area manager.

Standard Telephones and Cables Ltd., Connaught House, Aldwych, London W.C.2, announce the establishment of regional offices at Norwhich Union Buildings, City Square, Leeds 1, under the management of Mr. L. G. Miller, and at 49 Queen Street, Glasgow C.1, under the management of Mr. H. R. Walmesley.

Jones and Laughlin Steel Corporation announce that they contemplate the erection of a large integrated steel mill near Houston, Texas, with a capacity of 1,000,000 tons of ingots a year. The estimated cost of the new steel mill is between 250 and 350 million dollars.

The Tata Iron and Steel Company of India are to receive a loan of 75,000,000 dollars from the World Bank to assist the company's large scale expansion programme. It is contemplated to raise the company's annual output to 1,500,000 long tons of finished steel.

Bill Switchgear Ltd., Aston Lane, Perry Barr, Birmingham 20, is opening a branch office and stores at 23 Bedford Street, Belfast. Tel. No.: Belfast 20398. Mr. J. Ballentine will be manager of the office.

Electrofact Ltd., the British subsidiary of Electrofact N.V., Amsterdam, has been acquired by Hartley Electromotives Ltd., 37 Thurloe Street, London, S.W.7, and will be known as the Electrofact Division of Hartley Electromotives Ltd.

The manufacture and design development of the Electrofact range of industrial and laboratory pH instruments has been transferred to Hartley Electromotives factory at Monkmoor, Shrewsbury.

J.L.S. Engineering Co. Ltd. has moved into new works and offices at Abbeydale Works, Brook Street, Redditch, Worcs. Tel. No. 3397.

The Royal Dutch-Shell Group is contemplating a major pipeline for crude oil in Western Europe. The trunk line would run from Marseilles through Eastern France, Luxembourg, The Saar, Western Germany, Holland, and Belgium to the North Sea ports of Rotterdam and Antwerp. The cost of the project is estimated at about £100,000,000.

The Esso Petroleum Company, Shell-Mex and B.P. Ltd., and the California Texas Corporation will jointly erect and operate a new oil refinery to be built at a cost of £12,000,000 at Whitegate, Co. Cork, Eire. Construction is expected to take about three years. The refinery will have a capacity of 1,600,000 tons of crude oil per year.

Summary sheets of British Standards. In response to the wishes of industry the British Standards Institution has begun the publication of " summary sheets " which provide—in very concise form—the relevant working details, particularly tables of dimensions, needed by standards officers, engineers and designers, in their day-to-day work of applying British Standards. The first of these sheets contain summarized versions of the British Standard (B.S. 1768) for Unified precision hexagon bolts, screws, nuts (UNC and UNF threads) and plain washers—Normal series.

CONTRACTS

The Electriciteitsbedrijf Zuid-Holland N.V. (South Holland Power Supply Co.) has ordered two 75,000-kVA power transformers from **Metropolitan-Vickers Electrical Co. Ltd.** for installation at the Marconistraat substation in Rotterdam.

These transformers will be three-phase 50-c/s units of the ON/OB type, star/star/delta-connected and having a voltage ratio at no-load of 150/26.25/10.5 kV. They will be designed to have low losses, and the cores will be made of cold-reduced grain-oriented directional sheet steel.

The high voltage windings will have an impulse withstand level of 750 kV. They will be provided with eighteen tappings over a range of plus and minus 15% and will be fitted with the M-V Company's type " H " on-load tap-changing switch, arranged for remote electrical control.

A contract for the manufacture and delivery to site of two-200,000 kVA, three-phase, 60 cycle, 154/13.8 kV transformers has been awarded to the **English Electric Export and Trading Co. Ltd.,** by the **Tennessee Valley Authority of Chattanooga,** for the Reynolds Power Sub-station.

The value of the contract is approximately £200,000 and the transformers will be manufactured at the Company's Stafford Works. This is the third order to be placed with English Electric by the Tennessee Valley Authority, the previous two contracts cover equipment for the Rockwood and Johnsonville power stations.

The Swiss Posts and Telegraphs Department has recently placed an order with Standard Telephone et Radio S.A. Zürich for SHF Radio Equipment to link the capital city Berne with Geneva, providing 600 telephone circuits over a single radio channel, with facilities for future extensions. This will considerably augment the existing telephone network and cater for subsequent growth.

The equipment will be designed and manufactured in England by Standard Telephones and Cables Limited (associated with Standard Telephone et Radio S.A. Zürich) and will comprise terminals at Berne and Geneva with a repeater station at Chasseral.

The transmission path lies over mountainous country, and the section Chasseral-Geneva is some 70 miles (112 km) long, a considerable distance to cover in one " hop ". This will be accomplished, however, with the Standard SHF System incorporating the newly-developed Standard 5-watt travelling-wave amplifier.

Fertilisers & Chemicals, Ltd., Travancore, have just signed a contact with Chemiebau Dr. A. Zieren G.m.b.H., for the construction of a new sulphuric acid contact plant. This plant will utilize elemental sulphur for the production of 160 tons of monohydrate per day. The new plant, together with two existing units, makes F.A.C.T. the largest manufacturer of sulphuric acid in India. The acid will be used partly for increasing their production of ammonium sulphate and also for a new ammonium phosphate plant which forms parts of a major development scheme. In the United Kingdom the Chemiebau Zieren design of sulphuric acid plant is available through The Power-Gas Corporation Ltd., Stockton-on-Tees.

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The rate for all classified advertisements is 6d. per word ; in bold print 9d. per word ; minimum order 6s. Box-number advertisements 1s. extra. Instructions, together with remittance, must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

SITUATIONS VACANT

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Experimental Physicists holding H.N.C. or G.C.E.

ENGINEERS

Men holding Honours or Pass Degrees in Mechanical Engineering with some experience in industry. In addition there are vacancies for assistants holding H.N.C. in Mechanical Engineering and who have served an apprenticeship.

DESIGNERS

Men having design experience, and holding Honours or Pass Degrees in Mechanical Engineering, and having practical experience, preferably in Marine Engineering, or on the technical side for the generation of power for use on land.

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Men who have completed their National Service, for work in connection with the above, and also for the general development of prototypes.

Applications, giving full details, should be sent to the above address.

VICKERS-ARMSTRONGS (ENGINEERS) LIMITED
BARROW-IN-FURNESS, LANCASHIRE

Are seeking technical staff, as under, for research and development work in connection with the application of new methods to the propulsion of ships.

ENGINEERS

Engineers holding Honours Degrees with experience in the field of marine or mechanical engineering.

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Men who have completed their National Service, for work in connection with the above, and also for the general development of prototypes, and the production and installation of machinery.

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STAFF MANAGER,
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A small expanding Engineering Company in Manchester requires Agencies in the following fields:
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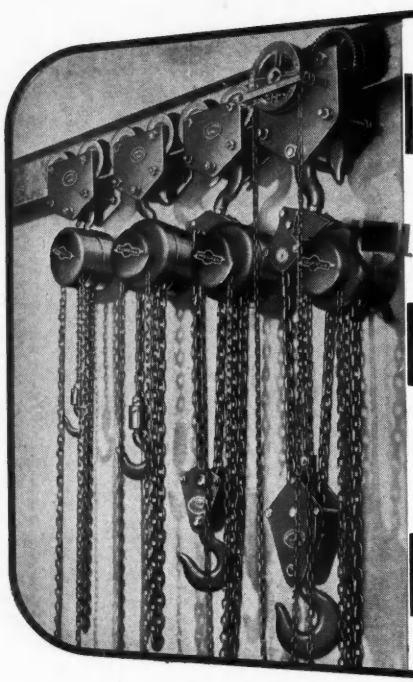

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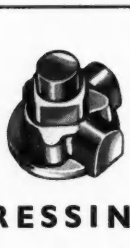

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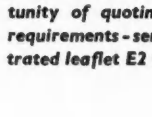

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BOOKS RECEIVED

Industrial Research, 1956–1957. 3rd Edition. Advisory Editor, Percy Dunsheath, C.B.E., M.A., D.Sc. 444 pp. Publishers : Todd Publishing Group Limited, London. Sole British Distributors : George G. Harrap & Co., Ltd., 182 High Holborn, London, W.C.1. Price : 63/–.

With the rapid expansion of industrial research, it is only natural that a reference book on this subject must increase its scope with each new edition. It is not surprising, therefore, that the third edition of this authoritative guide to all interested in industrial research contains, in addition to much fresh information, certain entirely new sections and the complete revision of existing sections. New sections include a " Directory of Commonwealth and Overseas Organizations interested in Industrial Research " and " Atomic Energy ", incorporating the whole of the activities of the United Kingdom Atomic Energy Authority, together with a directory of the chief officials and departmental heads of the Authority.

Appearing also for the first time are articles by Sir Ben Lockspeiser, Secretary to the Department of Scientific and Industrial Research, 1949–1956, and by Sir Norman Kipping, Director-General, Federation of British Industries. In these articles, Sir Ben reviews the steps taken by the Government to promote research in industry, while Sir Norman shows how industry itself, through research, is contributing vitally to the prosperity of the nation.

In addition, this useful book contains reference sections on careers, technical colleges, university laboratories, industrial-research consultants, and books and periodicals, together with statements of the activities of official and unofficial organizations and directories of officials and classified lists of official and unofficial bodies in the United Kingdom and overseas.

Modern Workshop Technology (*Part I : Materials and Processes*). 2nd Edition. Edited by H. Wright Baker, D.Sc., M.I.Mech.E. 520 pp. 217 illustrations. Publishers : Cleaver-Hume Press Ltd., 31 Wright's Lane, Kensington, London, W.8. Price : 35/–.

The second edition of this well-known and valuable book, which relates sound theoretical principles to the realities of contemporary factory techniques, has been extensively revised and extended. Thus, there are fresh chapters on the newer casting techniques (shell-moulding and investment casting), and on the production of steel wire and bright steel bars. In addition, Dr. Barwell's chapter on Plastics Engineering has been entirely recast and extended, while a new and detailed treatment of Mechanical Testing and Inspection has been given by Dr. Lamble. Finally, a considerable number of new and informative line-drawings has been added, while the greatly extended bibliography gives a selection of books which may conveniently be consulted on special topics. In short, as a reference book and companion for senior students working for their B.Sc. or A.M.I.Mech.E., and for young works engineers, it provides a wealth of practical information, critical discussion, tables, and statistics.

Part II of this work, to appear in 1957, will be a companion volume and will deal with Machine Tools and Metrology.

LATEST INDUSTRIAL LITERATURE

1. **Class " E " Switchgear.** In a beautifully produced and illustrated 16-page booklet, details are given of Class " E " switchgear, developed for the control of auxiliaries and motor loads in systems with high concentrations of power, such as power stations and steel works. The gear includes truck-mounted air-break circuit-breaker mechanisms, and special equipment which enables the breaker to be isolated without having to move the breaker truck. A mechanical circuit-condition indicator is mounted in a window on the front panel, and a duplicate busbar unit is available within single busbar dimensions. The maximum rating is 3300 V, 2000 A, with a breaking capacity of 150 MVA.

2. **Electrical Wiring Accessories.** In a beautifully produced and illustrated 70-page catalogue, details are given of a comprehensive range of electrical wiring accessories, including switches, socket-outlets and plugs, ceiling roses, lampholders, bell-pushes, indicator units, and switch-fuses. A useful feature of this catalogue is the inclusion of a detailed alphabetical contents list and a numerical index of catalogue list numbers.

3. **" Photography at Work ".** Issued by a firm whose name is a household word in the field of photography, this interesting, well-produced, and excellently illustrated 24-page publication pinpoints a few of the many ways in which photography is being used nowadays in commerce and industry. Not only are examples given of how this has been achieved in specific cases, but suggestions are also given regarding some of the ways photography may be able to help in certain cases. Many of the illustrations have been supplied, together with the necessary data, by leading industrial organizations in Great Britain.

4. **Industrial Smoke-Density Indicator.** Designed to give continuous indication of smoke density by measuring the obscuration record of smoke emission and to give warning when excessive smoke conditions prevail, the industrial smoke-density indicator described in an illustrated pamphlet is an aid to smoke abatement and a guide to efficient combustion. The improved equipment detailed in this pamphlet incorporates many advanced features, but is less expensive than the older models. It comprises a projector, a receiver, and a control unit incorporating an alarm relay and an indicating meter with a 6-in. scale.

A supplementary pamphlet describes and illustrates a neat floor-mounting cubicle for this equipment, making it into a compact unit and eliminating a large part of the installation costs.

5. **Electromagnetic Clutches and Brakes.** Details are contained in a 4-page brochure of a range of electromagnetic clutches and brakes produced by a firm with over fifty years of experience in this field. These clutches feature smooth and precise engagement and a controlled grip, with no end thrust. Moreover, they can easily be remotely controlled and have a negligible current consumption.

This brochure also contains details of a range of lifting magnets for handling many types of ferrous materials and for use with scrap, billets, etc., and information on a range of magnetizing units.

6. **Case-Hardening Process.** An improved method of nitriding, greatly simplified in comparison with existing nitriding processes, is described in a well-produced and illustrated 16-page booklet. The process, which has been referred to as " pressure-nitriding ", has numerous advantages ; thus, for instance, special nitriding furnaces are not required, any heat-treating furnace capable of maintaining a controlled temperature of about 1000°F being suitable. Moreover, nitriding is carried out in a closed retort which does not require circulation of ammonia or other gases, so that it is unnecessary to control flow rates and to check the decomposition of nitriding gases ; in addition, circulating fans are not required to produce uniform nitriding.

Other advantages of the process include improved case quality and a marked economy in initial investment for equipment. Furthermore, nitriding times to obtain a given " super-hard " case thickness are decreased, less attention is required during nitriding, grinding to remove objectionable " white-layer " is eliminated, and ammonia consumption is reduced by at least 90%.

7. **Portable Spray-Painting Outfits.** Issued by a leading manufacturer of such equipment, an illustrated pamphlet gives details of portable, trolley-mounted spray-painting outfits, designed to operate with electric motors or petrol engines. These units are ideal for rapid work on medium-size finishing and painting jobs, and are supplied complete with a suitable spray gun, a nozzle set, and a 20-ft length of $\frac{1}{16}$-in. air-hose with connections. Features of these outfits include quiet, vibrationless running, compact and robust construction, and complete freedom from condensation.

A supplementary series of catalogues, booklets, and pamphlets describes spray equipment for catalyst and additive materials, the care and operation of spray-painting equipment, spray-gun motion study, a selection guide to spray guns, and air-brush nozzles for artists and photographers.

8. **Spur-Gear Grinder** Designed for the grinding of fine-pitch spur gears on a mass-production basis, the spur-gear grinder described in a neatly conceived and executed 8-page brochure operates on the generating principle of gear-tooth development from the basic rack form, the grinding wheel being formed as a single-start spiral rib. The grinding process is continuous and is not interrupted by dividing operations. Gear forms up to 20 D.P. can be economically ground from the solid at rates comparable with those from orthodox hobbing.

This machine is particularly outstanding in the grinding of components having large numbers of teeth. Loss of production time, normally encountered through indexing, is avoided, and all teeth are uniformly ground from one dressing of the wheel. With this machine the grinding of fine-pitch serrations, etc., hitherto not a feasible proposition because of high production costs, is made possible.

9. **Corrugated Glass-Fibre Sheet.** Strong, shatter-proof, and translucent, a corrugated glass-fibre sheet material described in a 6-page brochure has been specially developed for efficient, economical, and durable roof lighting in factories and works, farms and dairies, greenhouses, etc. This material not only diffuses the light, but also cuts out a large proportion of infra-red rays, providing a clear light without glare or shadows, and keeping cool the space below.

Available in medium- and heavy-weight grades, with weights per sq ft of 5½ and 7 oz respectively, this glass-fibre sheet, which can easily be cut with a fine-tooth hacksaw, is supplied in standard profiles and is available in a range of colours.

10. **Hydraulic Infinitely Variable-Speed Gears.** In a neatly produced and illustrated 24-page catalogue, details and specifications are given of a range of hydraulic infinitely variable-speed gears of the positive-displacement-pump and motor-unit type, ensuring accuracy of speed control under varying load conditions. Of simple design and robust construction, these self-contained units are housed in a well-proportioned, dust-proof, fan-cooled casing, while all rotating parts are carried either in ball journals or on anti-friction bearings.

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